WHC Nomination Documentation

File name: 672.pdf UNESCO Region ASIA AND THE PACIFIC

SITE NAME ("TITLE") Ha Long Bay

DATE OF INSCRIPTION ("SUBJECT") 17/12/1994

STATE PARTY ("AUTHOR") VIETNAM

CRITERIA ("KEY WORDS") N (iii)

DECISION OF THE WORLD HERITAGE COMMITTEE:
18th Session
The Committee recalled that the Bureau at its last session referred the consideration of this nomination pending the establishment of a legal framework, a revision of the boundaries of the proposed site and the initiation of a managment programme. The Committee was satisfied to note that the Vietnamese authorities have revised the boundaries to nominate a smaller site which met natural heritage criterion (iii), introduced a reasonably satisfactory legislation and provided a boat and appointed a minimum number of staff to patrol the area.
The Committee therefore inscribed the site on the World Heritage List and recommended that the Vietnamese authorities cooperate with IUCN to:

a) review and further strengthen the legislation and its applicability to the protection of the site;
b) initiate processes to prepare a management plan, which will define, amongst others, objectives and a zoning scheme;
c) implement management activities such as purchase of basic equipment and appointing more staff to strengthen management of the site and,
d) conduct surveys to monitor the growing number of tourists visiting the area and plan regulatory measures.

BRIEF DESCRIPTION:
Ha Long Bay, located in the Gulf of Tonkin, includes some 1600 islands and islets forming a spectacular seascape of limestone pillars. Because of their precipitous nature, most of the islands are uninhabited and unaffected by man. The exceptional esthetic values of this site are complimented by its great biological interest.

1.b. State, province or region: Province: Quang Ninh

1.d Exact location: Long. 106°58’-107°22’ E ; Lat. 20°45’-20°56’

UNITED NATIONS
EDUCATIONAL, SCIENTIFIC AND CULTURAL
ORGANIZATION

Date Received:
Indentification No:

CONVENTION CONCERNING
THE PROTECTION
OF THE WORLD CULTURAL AND NATURAL HERITAGE

WORLD HERITAGE LIST

NOMINATION FORM
OF HA LONG BAY- VIETNAM
(PROPOSAL FOR RE-NOMINATION)

SECTION 3: DESCRIPTION.

a) Description of property:

The area proposed for inscription covers 434 sq. km in the heart of Ha Long Bay and encloses 775 islands. It includes nearly all the small limestone islands of the most significant landscape value and greatest scientific importance. The smaller islands are fenglin towers of 50m to 100m high with height to width ratios up to about 6. Many have vertical walls on all or most sides: these continue to evolve by rock falls and large slab failures. Very old cave remnants are preserved within many of the towers and many have foot caves that are relics of their undercutting at various levels.

The larger islands contain the conical hills of fengcong karst, the summits of which average 100m above sea level with some exceeding 200m. Apart from at their marine margins, vertical cliffs are minor components of the fengcong hills, as they have not been subjected to lateral undercutting. They also contain remnants of old cave passages.

Marine invasion of Ha Long Bay has added an extra element to the normal process of lateral undercutting of the limestone towers and islands. The most conspicuous feature is the main notch cut into the entire rocky coastline. Its deepest zone is generally between normal high and low tides, with a lesser undercut extending a metre higher, perhaps the effect of high wave action and Spring high tides. Other notches at higher levels were cut during times of higher sea levels and are no longer active.

Notches are a feature of limestone cliffs worldwide, but those of Ha Long Bay are exceptionally well developed and, at many sites, extend into arches and caves. This process of undercutting and subsequent erosion maintains the steep faces of the fenglin karst towers and thereby perpetuates the spectacular nature of the landscape.

A distinctive feature of Ha Long Bay is the abundance of lakes within the larger limestone islands: Dau Be Island, for example, has six enclosed lakes. All these island lakes occupy drowned dolines within the fengcong karst. Their depth profiles have not yet been surveyed: most appear to be deep, but some have shallow planation surfaces just below water level. Nearly all seem to be tidal. Seawater moves freely through the limestone, at some sites through sea-level caves that are traversable by boat, but elsewhere through inaccessible fissures. On Cong Do Island a freshwater lake appears to survive on a doline floor of clastic sediment but details of its geomorphology are unknown.

Most of the Bay is less than 10m deep: many of the areas of shallow sea between the islands appear to be submerged karst plains. However, the bedrock geology of the Bay has not yet been investigated and there is doubt about the composition of the two largest island-free areas in the centres of Ha Long and Bay Tu Long Bays.

All the limestone surfaces on the Ha Long Bay islands are fretted by dissolution. The outcrops, therefore, evolve into complex and irregular shapes with very sharp edges on the pinnacles, blades and ridges of remnant rock creating an inhospitable terrain. Deep and jagged open fissures carry rainwater into the cave systems beneath.

There is no continuous soil cover. Largely organic soil accumulates in some limestone fissures providing a rooting medium for the ubiquitous scrub vegetation: conspicuous larger plants include *Panadannus* and *Dracena* (Dragon's Skeleton). Many walls and slopes of the more massive limestone beds are scored by rillenkarren that may be many metres long.

All the limestone surfaces are black due to their invasion by blue-green algae; these live in the surface crust of the limestone and aid its pitting by biogenic dissolution. The algae extend down into the tidal area; marine algal forms are probably equally widespread but have not yet been documented.

Limestone caves are an important feature of Ha Long Bay. Three main types can be identified:

i) Old phreatic caves; these were the underground channels that drained surface water through fissures in the limestone and were enlarged by dissolution. Subsequent lowering of the water table and ground surface has left them dry and sometimes exposed by erosion. Others lie preserved but hidden within the limestone hills. Phreatic caves are distinguishable by their sloping passages and considerable vertical range. Active phreatic caves must exist within the deeper limestone, but none has yet been discovered.

ii) Old karstic foot caves formed by lateral undercutting at base level. They may be quite small notches at the base of limestone cliffs or may extend back into larger cave systems within the limestone. They are distinguished by their passages being close to the horizontal and often cutting across rather than following, the geological structure. There are no active foot caves at Ha Long Bay because the sites of their development have been invaded by the sea to become marine caves.

iii) Marine notch caves, formed at sea level where rock structures are powerfully eroded and eventually reduced to a wave cut platform. This process is continuing today. Dissolution of the limestone allows cliff notches to be readily deepened and extended into caves. Many extend right through the limestone hills into drowned dolines, which are now tidal lakes or bays. A distinguishing feature of marine notch caves is their absolutely smooth and horizontal ceilings cut right through the limestone. The flat ceilings of Ha Long Bay's marine notch caves are above present high water levels and many are draped with stalactites. They are old erosion surfaces created largely by dissolution in the Pleistocene era when sea levels were higher.

Further, more detailed, description of the evolution and present status of the limestone karst landforms and caves of Ha Long Bay can be found in Waltham, 1998 (pp. 10-34).

b) History and Development:

i) GEOLOGICAL HISTORY:

The complex geographical and geomorphic history of Ha Long Bay is summarised in tabular form in tables 1 and 2. For greater detail see Waltham, 1998 and Than, T.D., 1998.

TABLE 1: THE GEOLOGICAL HISTORY OF HA LONG BAY.

Era	Period		Events
Cenozoic	Anthro-pogene	Holocene	Marine transgression, after the world's deglaciation, overruns the coastal areas to form the modern Ha Long Bay. This is mainly a land environment with a developing karst landscape and river systems. Systems of caves are formed at heights of 10-15m, 20-30m, and 40-60m
		Pleistocene	A marine transgression forms the ancient Ha Long Bay. Previously the sea level had been 100-200m lower than today and well outside the modern coastline during the cold stages of the Ice Ages.
	Neogene		Tectonic downwarpings of Cua Luc and Ha Long Bays. Anpi Orogeny earth movements on the Dong Trieu Arc.
	Paleogene		The East Ocean is formed. River erosion and alluvial deposition forms a large peneplain.
Mesozoic	Cretaceous Jurassic		A continental environment with orogenic movements of the land. Erosion processes are strong.
	Triassic		A land environment, where tectonic downwarping creates a coal swamp basin, is followed by strong movements of the Indonesian orogeny.
Paleozoic	Permian		Downwarping disturbs the coastline creating a land environment.
	Carboniferous		A shallow, warm sea enlarges from the west, rich in sea creatures including coral, foraminfera, brachiopods and crinoids. Limestone, over a thousand metres thick, is formed.
	Devonian		Ha Long Bay is a land area. Nearby, the Quan Lan archipeligo, Trang Kehn, Do Son and Cat Ba were downwarpings invaded by the sea.
	Silurian Ordovician		Open sea with deep water in the Katazia geosyncline. The sea extends to the west, but the East Ocean is a landmass.
	Cambrian		Land.
Proterozoic and Archean			Unknown.

TABLE 2 — THE DEVELOPMENT OF HA LONG BAY IN THE HOLOCENE PERIOD

Epoch		Stage	Years before present	Ha Long Bay	Cua Luc Bay	Bach Dang River	Archeological and historic events
	Late	6	1,000	The Bay enlarges: its fresh water mixes with salt water and fresh marine notches develop. Coral grows and the coast erodes.	The Bay becomes an estuary and mangrove swamps are reduced by erosion.	An estuary	The third anti-Yuan resistance. The first Bach Dang naval battle is fought.
		5	2,000	The Bay is narrow and accumulates a mud floor. Mangrove swamps form at the shores.	An estuary with mangrove forests.	The coastal downwarpings cause mangroves to grow.	
		4	3,000	The Bay enlarges, developing notches at 3.0 to 3.5m.	A marine bay.	A marine bay - coastal downwarping.	The Dong Son Culture. Vestiges of Phuong Nam (Uong Bi) and Viet Khe (Thuy Nguyen).
Holocene	Middle	3	4,000	The sea retreats and the land expands. Mangrove swamps form.	A freshwater lake.	Continental swamps along the coast.	Vestiges of Trang Kehn (Phung Nguyen Culture) Ha Long Culture
		2	7,000	Marine transgression. The Bay is at its largest area. Coral develops.	A marine bay is at its largest area.	A marine bay. Coastal downwarping	Pre-Ha Long Culture
Pleistocene	Early Late	1	11,000	Marine transgression as the sea level rises from 120m deep outside the mouth of the Bay.	Continental lake	Continental deltas, lakes and bogs.	Hoa Binh and Bac Son Cultures

ii) HISTORICAL INTERACTION WITH HUMANKIND:

Ha Long Bay may have been inhabited from the Old Stone Age: an ancient settlement and tool factory in Tan Mai village has yielded artifacts which seem to be from that period but these discoveries have not yet been authenticated. However, there are several confirmed New Stone Age settlements in and around the Bay, denoting continuous settlement for at least the last ten thousand years. Human remains and artifacts found in caves and grottos indicate their use as habitations between five and ten thousand years ago. One of the grottos has given its name to these people of the Soi Nhu, where remains of the Pre-Ha Long Culture have been found. Several sites used by peoples of the later Neolithic Ha Long Culture suggest that the Bay was being used for shelter and for the exploitation of its mineral and food resources. Bronze implements show the later development of this culture and the beginnings of wider trade routes.

Ha Long Bay's favourable geographical location, equable climate and rich marine and arable food potential was exploited by the Chinese during their ten centuries of domination of Viet Nam. By the time of the country's liberation from oppressive Chinese rule in 939 AD, Ha Long Bay had developed as a significant trading gateway, its port rivalling those of China. Under later dynasties, trade protection measures were introduced and its significance diminished.

The Ha Long Bay area became an important centre for Buddhism in the 13th and 14th centuries and many important remains of religious significance have been found on several sites.

Mineral extraction, particularly coal, become significant under French rule and has continued after independence. In 1883, French warships entered Ha Long Bay and took control of the mining areas of Hong Gai. French coal companies, finding abundant, high-quality anthracite deposits, duly exploited them and the people who worked in the mines. These oppressive conditions made Hong Gai a fertile recruiting ground for the communist ideology when it entered Viet Nam in the early part of the twentieth century. Hong Gai became a centre for resistance against French rule. An infamous massacre by the French at Hong Gai in 1946 sparked off nationwide resistance and nine years of violence leading ultimately to the victory at Dien Bien Phu.

In the following years of starvation and deprivation during the struggle against American forces, the Ha Long tradition of resistance continued in the Bay and on the islands. In 1964, a series of heavy bombing raids completely destroyed Hong Gai and caused severe damage elsewhere in the area. After liberation and 'doi moi', the economic reform programme, the Ha Long Bay area has seen economic growth, the development of democratic institutions and stable government. The rich resources of the area, its agriculture, marine products, minerals, natural scenic beauty and the industriousness and ingenuity of its people are again being successfully exploited.

This long tradition of fortitude and fierce loyalty to Ha Long Bay has created great civic pride and a strong desire for the beauty of the Bay to be recognised by, and shared with, the world community through its position as a World Heritage Area.

iii) MYTH AND CULTURE;

Ha Long Bay has great significance in Viet Nam's mythology. Its name, although acquired as recently as the nineteenth century, has its roots deep in legend. When literally translated, it means 'Bay of Descending Dragons" and refers to the Mother Dragon and her Child Dragons creating the islands of the Bay to frustrate and defeat foreign aggressors in ancient times. So the story has it, the Dragons remain at the Bay to awaken if the Vietnamese are again imperilled.

Since then, Ha Long Bay has been a source of inspiration for poets, musicians, painters, film makers, etc., not only from Viet Nam, but from countries all over the world.

c) **Form and date of most recent records of site:**

i) "Limestone Karst of Ha Long Bay" - Geomorphic research study and report (Waltham, 1998)

ii) "Strategic Planning and Management of the Ha Long Bay Management World Heritage Centre" - Management development study and report (Muldoon,!998)

iii) "Geological History of Ha Long Bay" - Geological research study (Tran Duc Than, 1998)

iv) "Report of matters relating to the management and preservation of the World Heritage Ha Long Bay in 1998" - Report to the Director of the World Heritage Centre, UNESCO (Ha Long Bay Management Department)

v) "Explanation Report on Bai Chay Construction Project" - Report to the World Heritage Centre, UNESCO (Ha Long Management Department, 1998)

vi) "The Study on Environmental Management for Ha Long Bay in the Socialist Republic of Vietnam: Inception Report" - Environmental study and report (Nippon Koei Co. Ltd./Metocean Co. Ltd., 1999)

vii) "Ha Long Bay - The Art Documentary"- Promotional video (Ha Long Bay Management Department, 1998)

viii) "Quang Ninh, Ha Long" - Promotional multimedia CD-ROM (Quang Ninh Tourism Department, 1999)

d) Present state of conservation:

In general terms, Ha Long Bay is in a sound state of conservation. Its scenic beauty, geology, biodiversity and cultural heritage have all been preserved more or less intact. Where, in the past, inadvertent damage has been caused it has been minimal and has been rectified wherever possible. A recent specialist research report on the geomorphology of the area found no indications of significant unnatural degradation (Waltham, 1998). The geomorphic evolution of the landscape is, of course, on going and it is our generation's responsibility to ensure that the process continues to be entirely natural.

e) Policies and programmes related to the presentation and promotion of the property:

It is the Department's policy to promote the attributes and values of the World Heritage Area widely within the local community and beyond. Its aim is to raise public awareness of the issues and regulations involved in the conservation and proper management of Ha Long Bay and to promote responsible attitudes towards its safekeeping for future generations.

To this end, the Department promotes the property:

to the local community, by: -

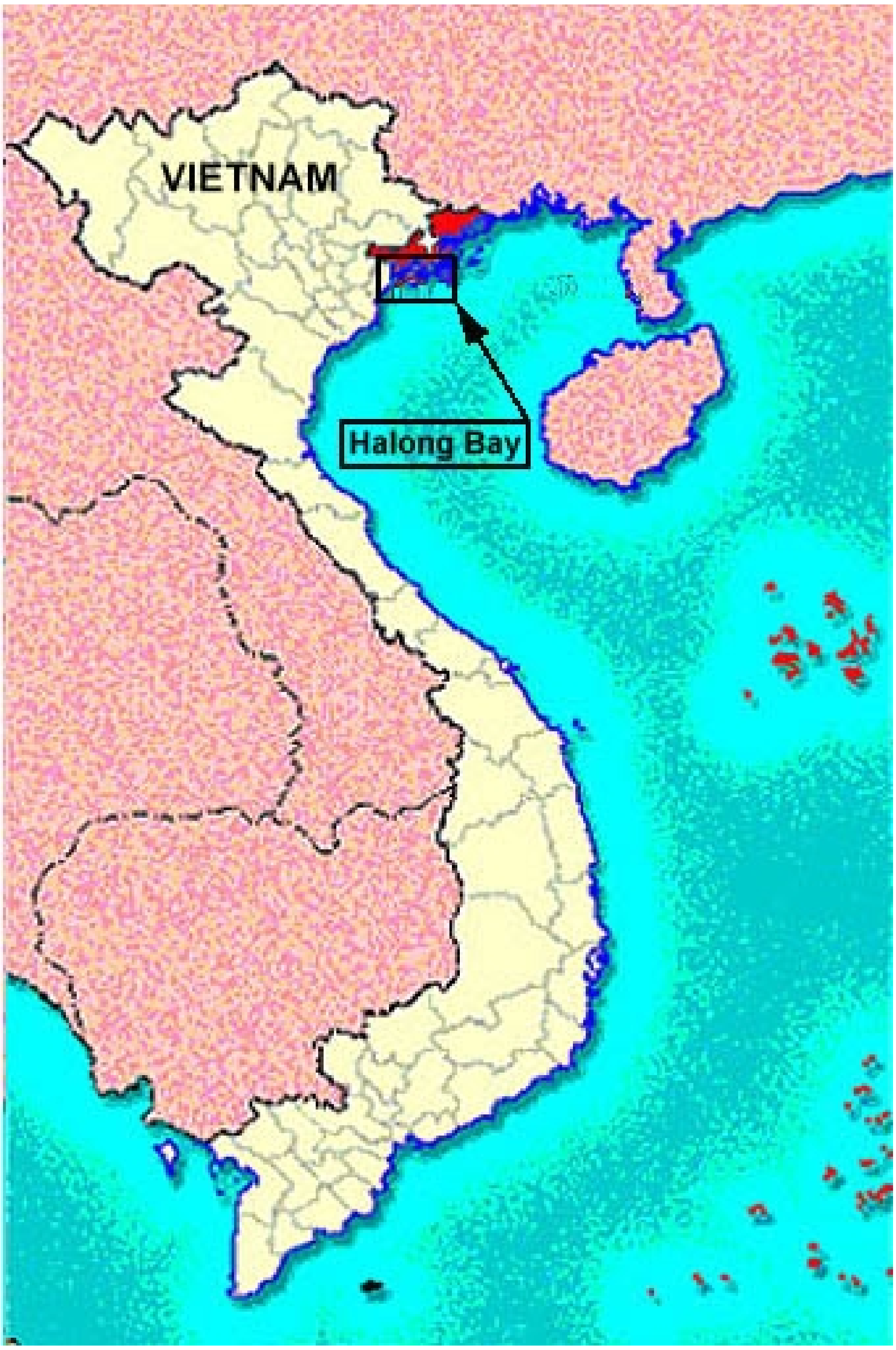
Educational activities in schools.
Local publicity and information.

to tourists, by: -

Information, education and the promotion of responsible behaviour by the tourist guides.
Guide books.

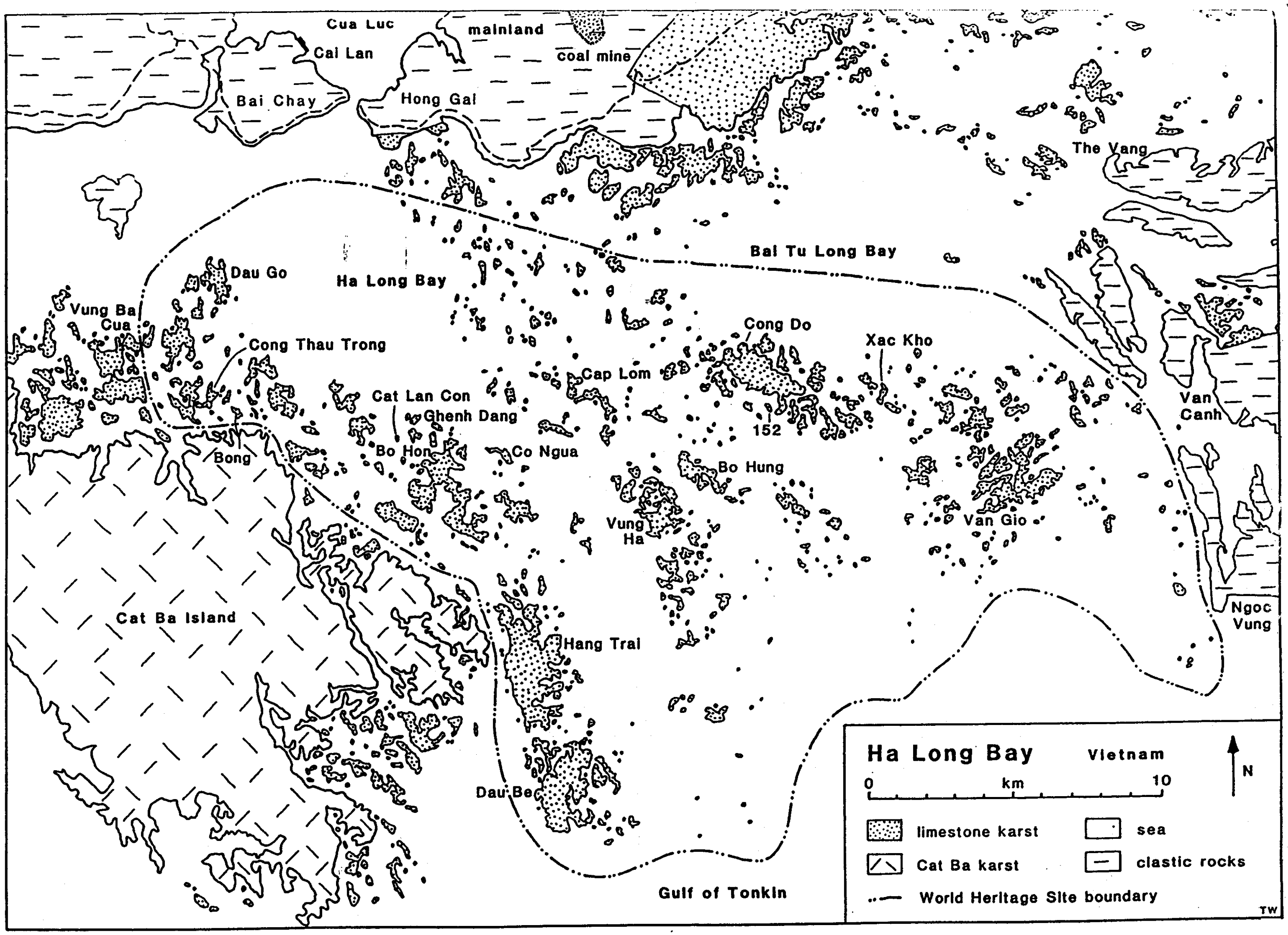
to the wider community, by: -

Programmes and interviews on television and radio.
Articles and news item in newspapers and magazines.
Research data and facilities made available to the scientific community.
Communications via specialist journals and, later this year, an Internet web site.
Publicity material such as CD-RM, videos, tapes, books, slides and postcards.



Map 1: Location Map – Ha Long Bay

Map 2: Site Map – Ha Long Bay



Carte 2: Carte du site – Baie d’Ha Long

Limestone karst

of

Ha Long Bay

Vietnam

An assessment of the karst geomorphology of
the World Heritage Site

for

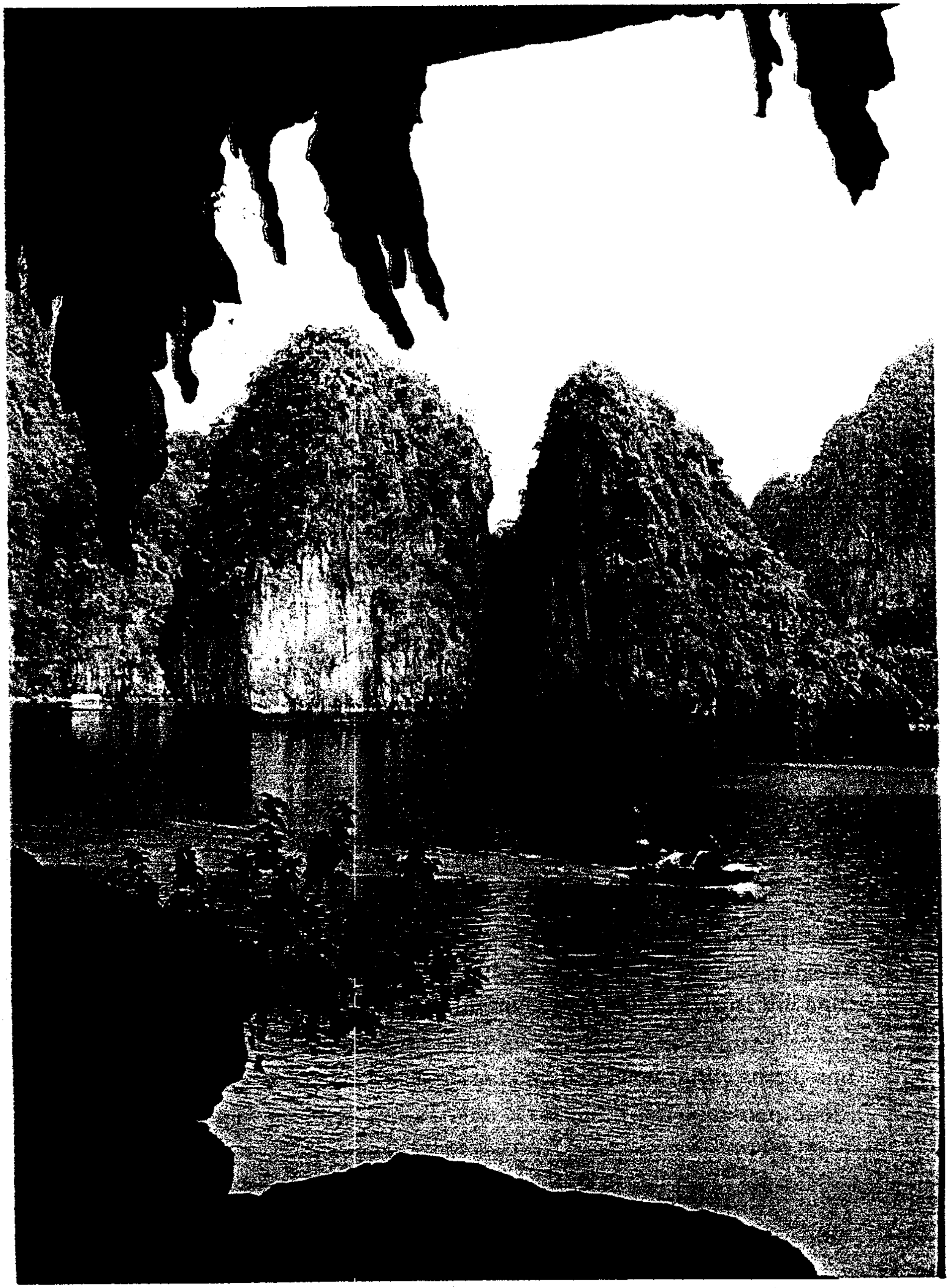
The World Conservation Union
and
The Management Department of Ha Long Bay

by

Tony Waltham

Engineering Geology Report # 806
Nottingham Trent University, UK

October 1998



Summary

Limestone karst of Ha Long Bay

- Ha Long Bay is a magnificent limestone landscape of fengcong and fenglin karst that has been invaded by the sea.
- The scientific value of the Ha Long Bay World Heritage Site should be recognised; the site is internationally important for its limestone karst geomorphology.
- The numerous islands within Ha Long Bay contain landforms, caves and cave deposits that provide evidence of a long history of erosion and landscape evolution.
- Continued coal mining and the current expansion of the port structures adjacent to and within Ha Long Bay present no significant threat to the values of the site geomorphology, as long as they are managed sensitively.
- There is a continuing need for careful control of development within Ha Long Bay by a managenment structure which gives due respect to the important environmental values of the site.
- The scientific data base on Ha Long Bay is currently small, and the site warrants a programme of research and documentation.

Contents

Limestone karst of Ha Long Bay

Ha Long Bay is distingushed by the hundreds of small limestone islands which rise steeply or vertically from its shallow waters. Its dramatic and beautiful landscape is deservedly famous as one of the world's outstanding natural sights, but it is also a geomorphological feature of international significance.

The bay lies on the northeastern coast of Vietnam, immediately east of the Red River delta (Figure 1). It is bounded on the north by the mainland hills either side of Halong City (also known as Hong Gai), to the south by the open waters of the Gulf of Tonkin, and to the west by Cat Ba Island; its eastern boundary is loosely defined where a scatter of small limestone islands continues in an arm of the bay between the mainland and the complex of larger sandstone islands around and including Tra Ban Island. Within these boundaries, Ha Long Bay has an area of about 1500 km^2, and contains nearly 2000 limestone islands. An eastern section of more open water between the limestone islands is also known as Bai Tu Long Bay (Figure 2).

The World Heritage Site

In 1962, the natural scenic beauty of Ha Long Bay was officially recognised as important to the nation of Vietnam. In December 1994, Ha Long was added to the UNESCO list of World Heritage Sites in recognition of the exceptional values of its landscape. The World Heritage Site covers 434 km^2 in the heart of the bay (Figure 2), and encloses 775 islands; it thereby includes nearly all the small limestone islands of the highest landscape value and scientific importance.

The following report is based on eight days of field observations in September 1998 together with data extracted from the limited amount of published and unpublished material available on the geology and geomorphology of the bay. Included comments on the geomorphological history should be regarded as preliminary deductions; these will be subject to debate and modification when further field data have been gathered.

Locality names are translated into English, except for the cave names which are left in Vietnamese. The key terms are:

dao = large island,
hon = small island, or rocky tower (nearly all the bay islands),
hang = cave that is a tunnel or long passage,
dong = cave that is essentially a single or multiple chamber.

All islands and caves referred to in this text are located on the Figures 2 and 11.

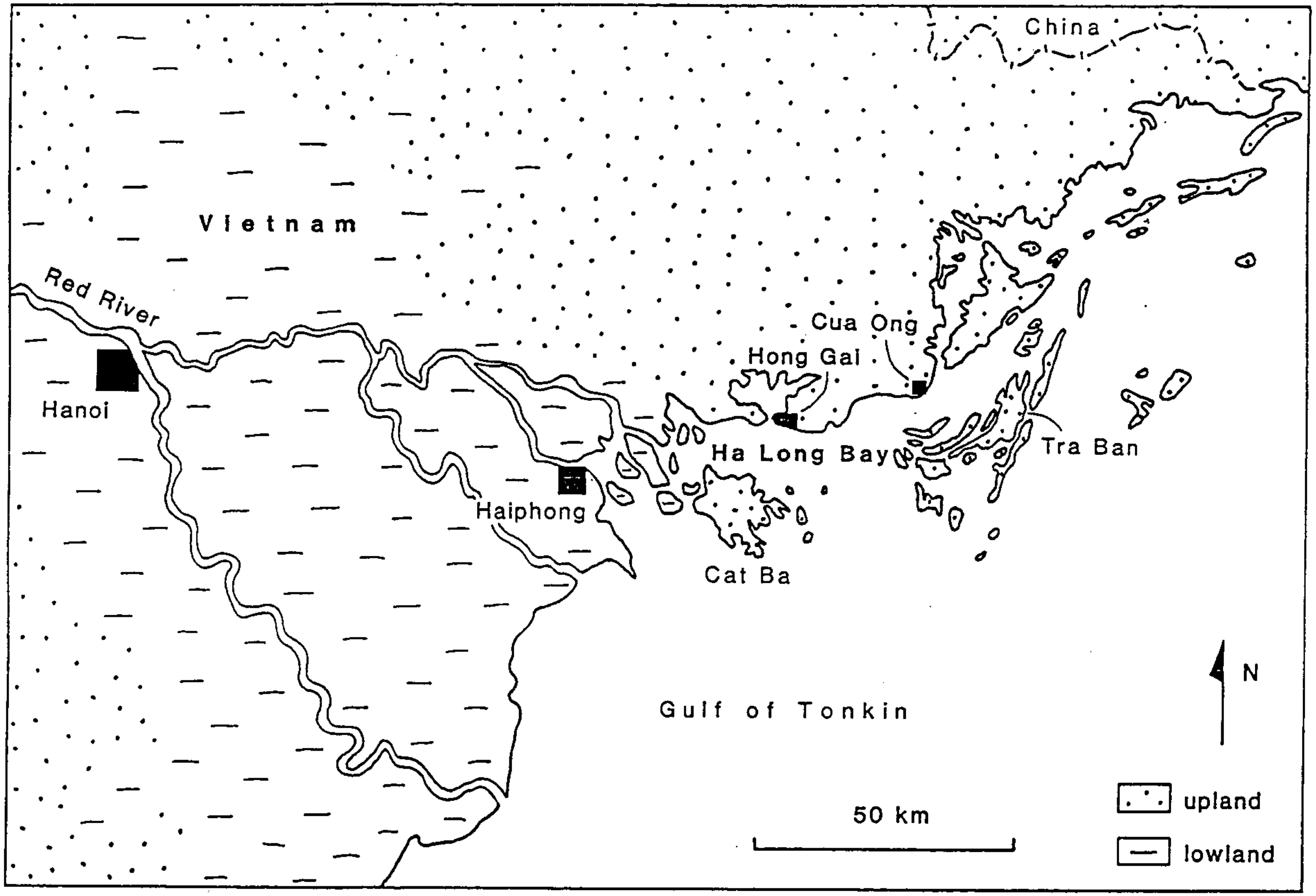


Figure 1. Outline map of northern Vietnam showing the relationship of Ha Long Bay to the Red River delta area.

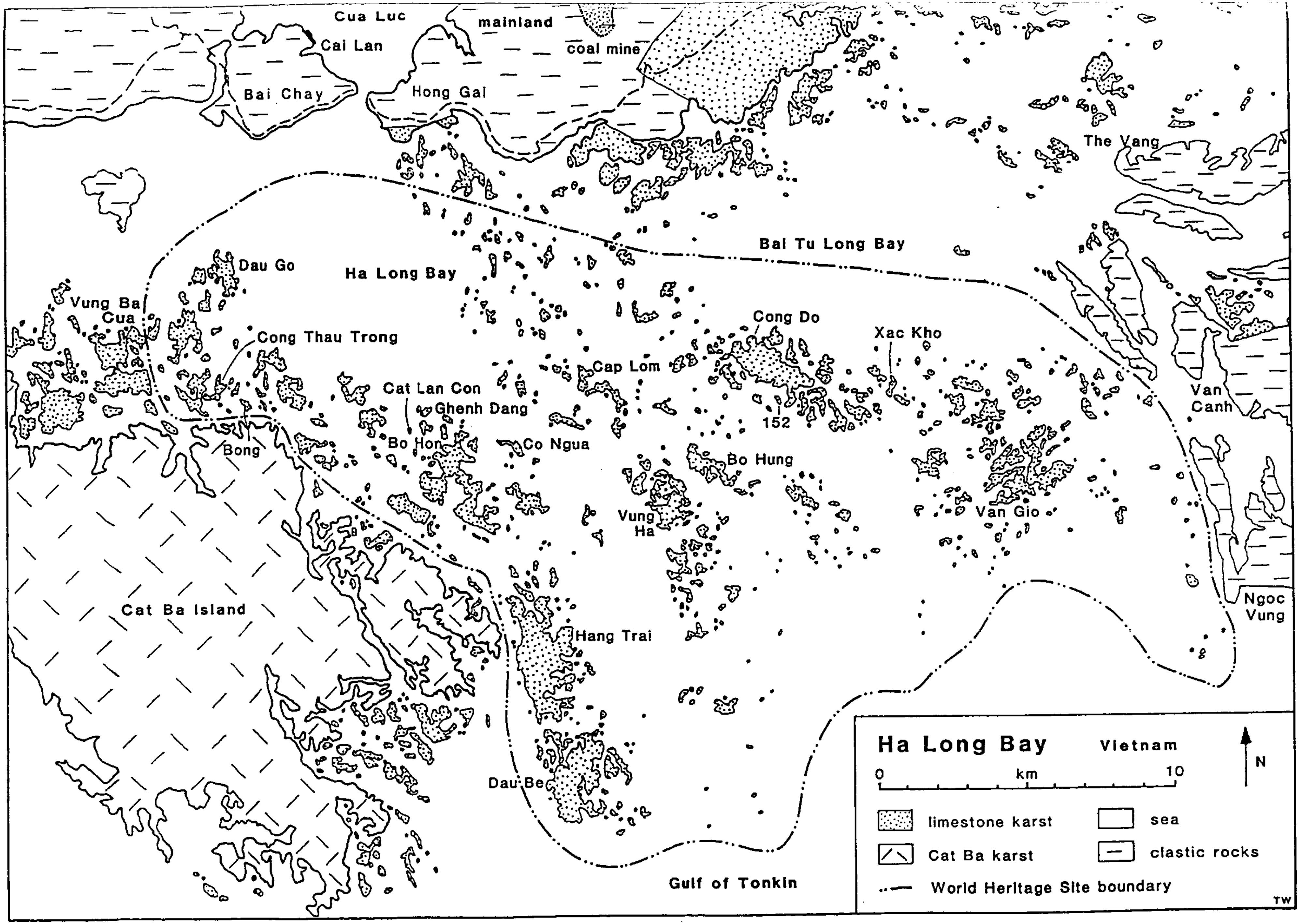


Figure 2. The World Heritage Site of Ha Long Bay; location of named sites (except caves which are on Figure 11).

Geomorphology of the limestone karst

A karst landscape is defined as one that has distinctive landforms because it is developed on a rock which has efficient underground drainage. Karst is therefore developed most widely on cavernous limestone. The resultant landscapes tend to have high and spectacular relief, and the specific landforms are largely related to climate and climatic history, where the most mature are developed within the tropical regions.

Karst geomorphology in the Vietnam environment

The evolution of a limestone terraine into a mature karst landscape is a long and complex process involving limestone dissolution (both at the soil-rock interface and also underground) and mechanical undercutting (both on steep slopes and within caves). The complete cycle can only evolve in a thick limestone sequence in a warm and wet climatic environment, where the dramatic landforms of cone and tower karst may then develop. These conditions do exist in Vietnam, and Ha Long Bay is the finest of many excellent examples of mature karst within the nation.

The sequence of stages in the evolution of a karst landscape are outlined in Figure 3. This is a very simplified version of a complex chain of processes, but it demonstrates the broad relationships between the different types of landscape seen in Ha Long Bay and other karst regions. The full evolutionary sequence can only develop in a region which has:

1 very thick limestone,
2 warm and wet climates,
and 3 slow overall tectonic uplift.

These conditions are best developed in the tropical zones of Southeast Asia, which therefore has the world's most important and most extensive regions of mature karst.

In other conditions, karst landscapes do not develop to full maturity. If the limestone is not very thick, the entire sequence is eroded away to expose underlying non-carbonates before the karst has matured. Overall surface lowering continues throughout the evolution, so that a limestone thickness of about 1000 m is generally required to allow maturity to the tower karst of stage 7 (which is the type present in Ha Long Bay). In colder and/or drier climates, frost shattering, reduced dissolution and Pleistocene glacial interruptions lead to the development of alpine karst, where doline fields are the common link to the stages in tropical karst (Figure 3); periglacial conditions favour the development of fluvial karst with dry valleys and dolines. Impure limestones and very thick derived soils both lead to slope degradation so that more rounded forms of cone karst develop.

Slow tectonic uplift is essential to the evolution from stage 6 to 7. The uplift rate has to be matched by the rate of dissolutional lowering of the limestone plains; then the plain is slowly lowered. This progresses faster than subaerial denudation of the limestone towers, which therefore slowly rise with the tectonic uplift. If uplift is too fast, the landscape is rejuvenated and returns to a fencong karst of stages 3 or 4. If upift is too slow, lateral planation erodes the towers so that they degrade and diminish as they advance to stages 8 and

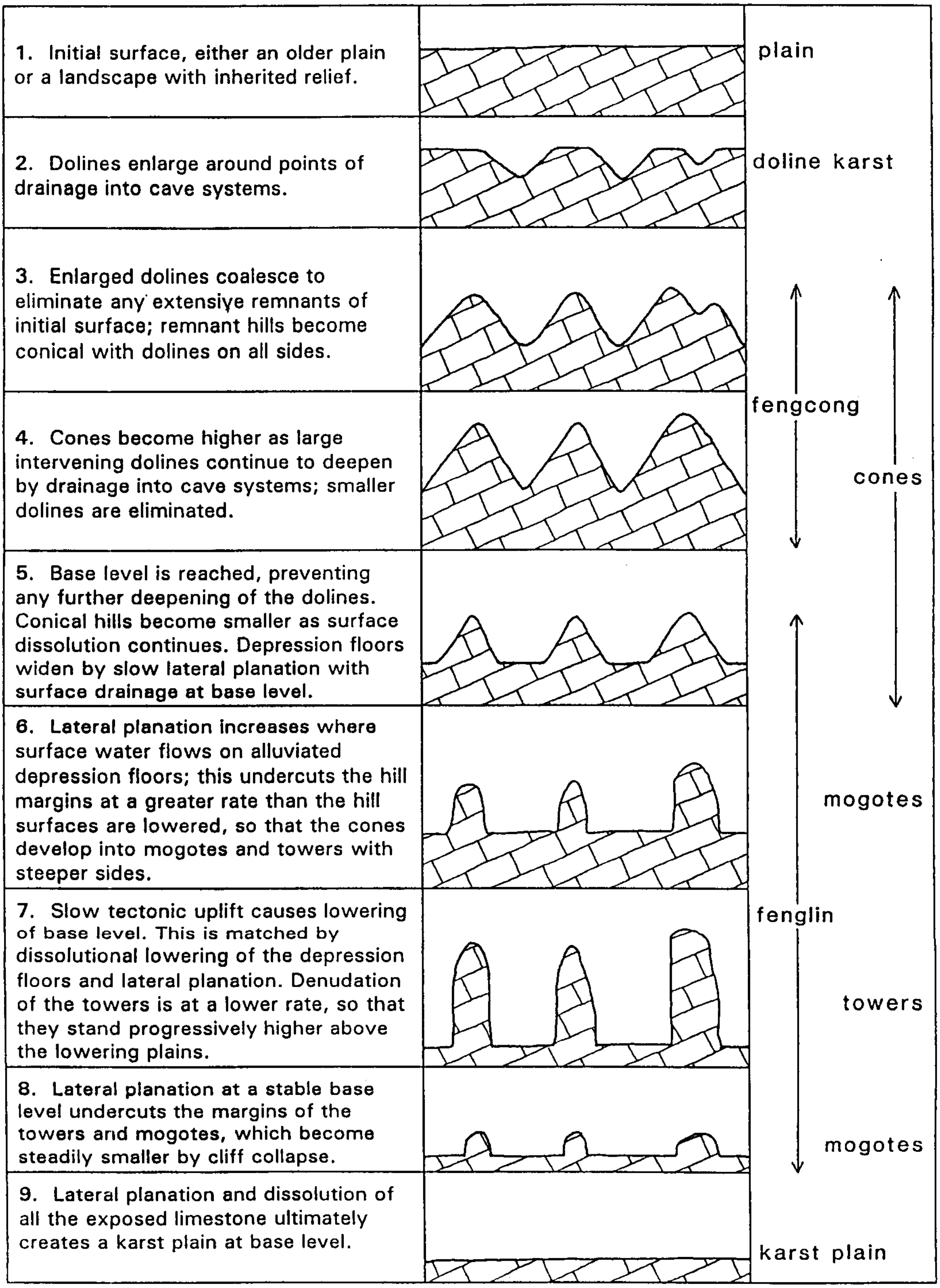


Figure 3. Schematic outline of the evolution of a limestone landscape into a mature fenglin karst.

then 9. Lateral planation and plain lowering is normally most effective beneath an alluvial cover; this has to be continually replenished by clastic sediment carried in and through by drainage from adjacent hills of non-carbonate rocks. The extreme forms of tower karst can only develop where all these conditions are met. Irregular uplift rates cause cyclic development, and create fencong karsts with peaks rising to different levels.

Mature karst landscapes are defined and described by a combination of two terminologies. Western geologists describe the shapes of the limestone hills. Cones have slopes between 30° and 60°, while mogotes and towers have steeper slopes; mogotes have heights roughly equal to their widths, and towers are higher (Figure 3). Dolines are closed depressions which drain into caves. Chinese geologists describe the grouping of hills with respect to intervening flatlands. Fengcong means peak cluster, where the hills are adjacent to each other and are generally conical. Fenglin means peak forest, where hills are isolated and generally have their sides undercut by lateral planation so that they are steepened into towers. Relationships between Western and Chinese terminologies are shown in Figure 3.

Karst landforms of Ha Long Bay

The strong pure limestones of Ha Long Bay have been eroded into a mature landscape of fengcong and fenglin karst. This evolved by normal subaerial erosion of the limestone, but was then invaded and slightly modified by the sea at a late stage.

The bay area contains landscape elements of fengcong, fenglin and karst plain. These are not separate evolutionary stages but are the products of natural non-uniform processes denuding a large mass of limestone.

The hundreds of rocky islands which form the most beautiful and famous landscapes in the bay are individual towers in a classic fenglin landscape where the intervening plains have been submerged by the sea (Figures 6 and 7). Most towers reach heights of 50 to 100 m, with height/width ratios up to about 6. Many towers have vertical walls on all or most sides; these continue to evolve by rockfalls and large slab failures. A large slab peeled off Bong Island in 1997 to create a new vertical face; the main failure surface was on vertical fractures, part of which had been opened to form a cave subsequently partly refilled with large stalactites, and the fallen block of around 500 m^3 now lies in the sea where it is being eroded by dissolution and wave action. Many of the towers have very old cave remnants preserved within them, and many have foot caves that are relicts of their undercutting at various levels.

Clusters of limestone hills form the larger islands within Ha Long Bay, and represent fine examples of fengcong karst (Figure 8). Summits are generally at around 100 m above sea level, and the highest peaks reach heights of over 200 m. Their profiles are mostly very steep cones; except around their marine margins, vertical cliffs are only minor components, as they have not been subject to lateral undercutting where their internal dolines do not reach down to base level. These conical hills also contain remnants of old cave passages (Figure 4). Some of the fengcong hills have individual slopes or sides which are formed on steep bedding planes within the limestone; beyond these sites the geological structure has very little

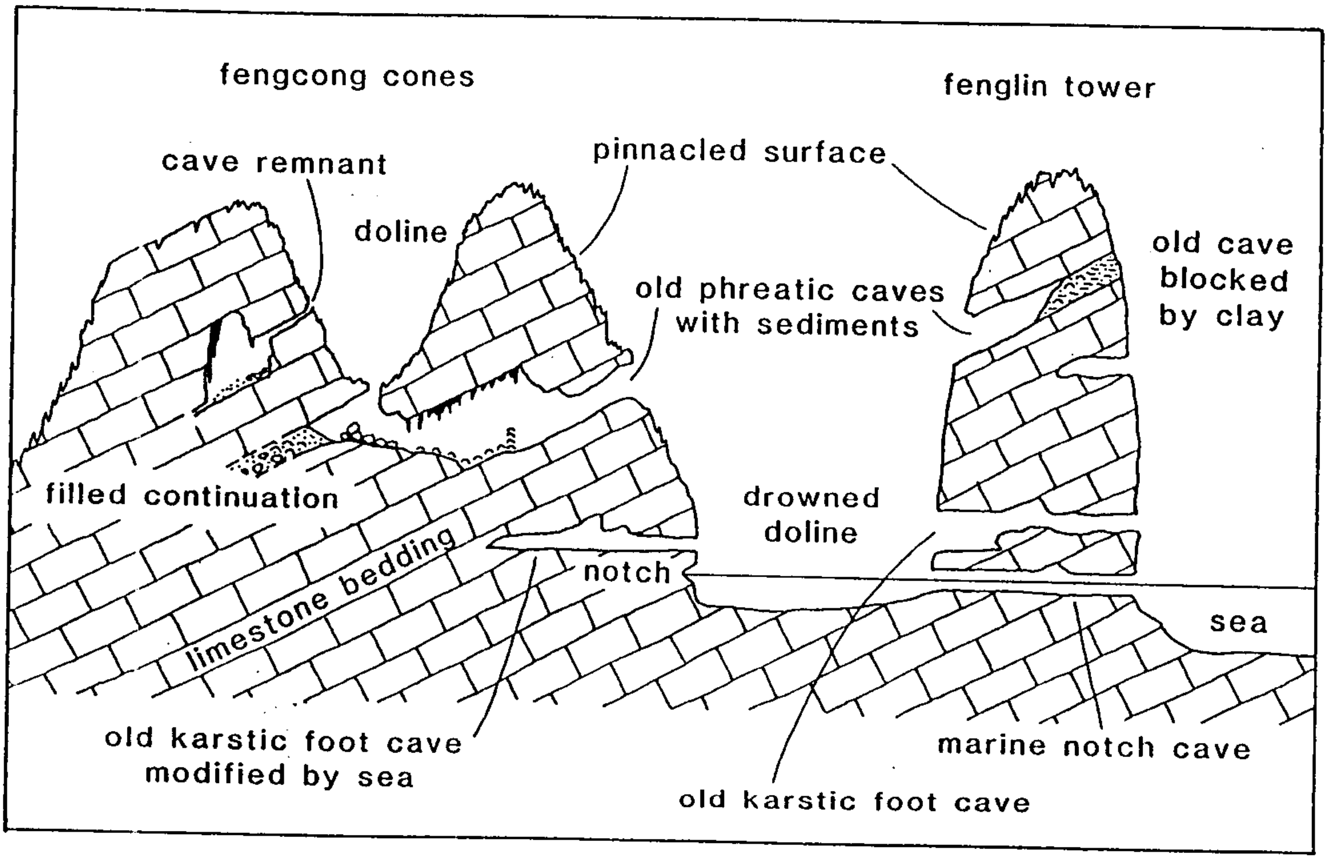


Figure 4. The main types of landforms and caves in the Ha Long Bay karst.

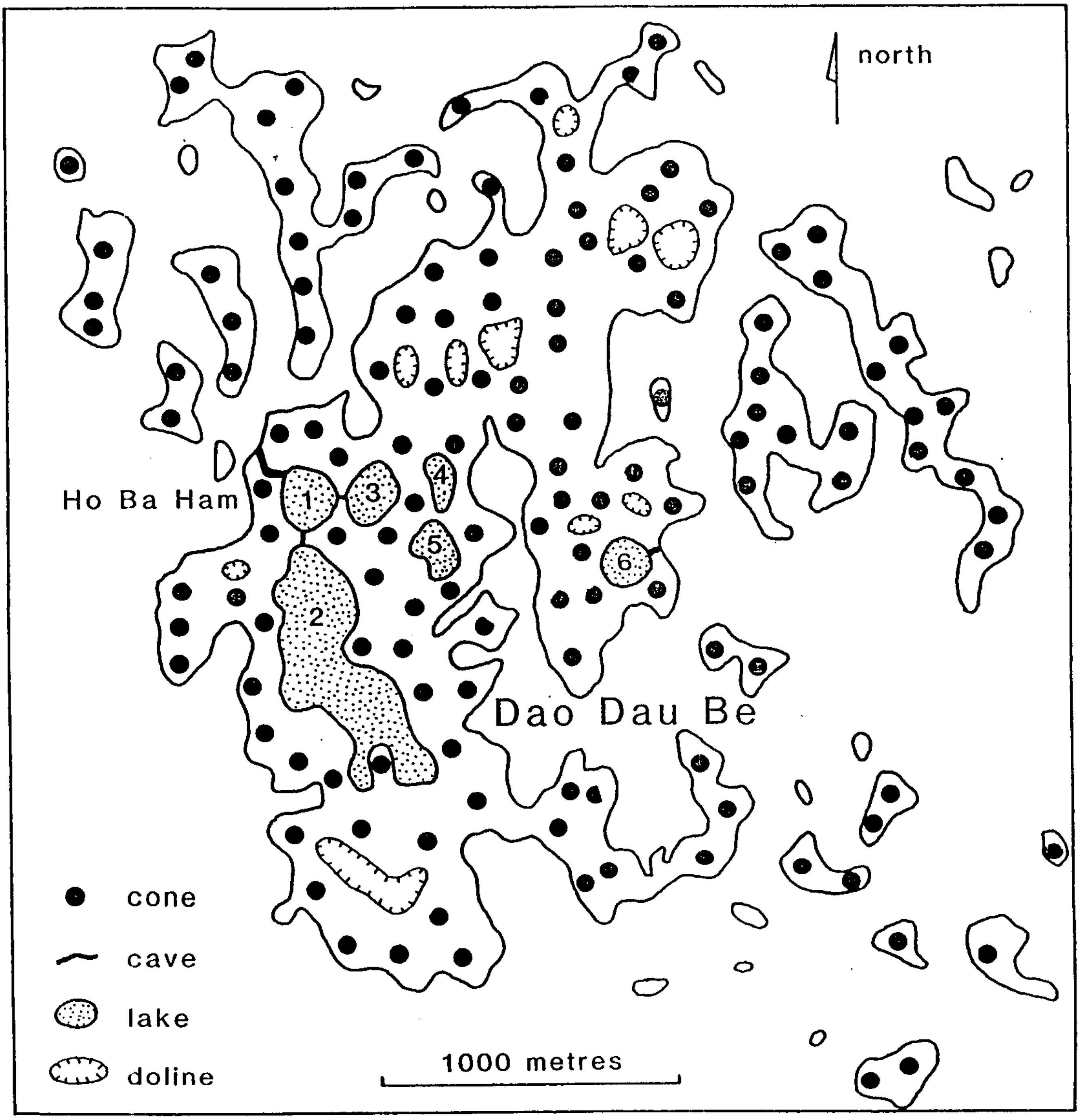


Figure 5. The conical hills of the fengcong karst which forms Dau Be Island, with the flooded dolines that are now tidal lakes connected by sea-level caves.

influence on the limestone hill profiles. Linear valleys which may be aligned on faults are also conspicuous by their absence.

A distinctive feature of Ha Long Bay is the abundance of lakes which lie inside the limestone islands. Dau Be Island, at the mouth of the bay, has six enclosed lakes, including those of Ho Ba Ham (Figure 5). All these island lakes occupy drowned dolines within the fencong karst (Figure 9). Their depth profiles have not yet been surveyed; most appear to be deep, but some have shallow areas over planation surfaces just below their water level. All those observed are tidal. Sea water moves freely through the limestone, at some sites through sea-level caves, which are traversable by boat (see below), but at other sites through inaccessible fissure networks. One freshwater lake has been reported, on the eastern part of Cong Do Island; it probably survives on a doline floor of clastic sediment, but details of its geomorphology are unknown.

Many of the areas of shallow sea between the limestone islands appear to be karst plains which have been submerged by the sea; most of the bay is less than 10 m deep. Clastic sediments cover much of the sea floor; most are probably of marine origin, though remnants of subaerial sediments from original karst plains may survive in the buried sequences. The bedrock geology of the bay floor has not been investigated, and there is doubt about the nature of the two largest areas of island-free bay waters, in the centres of both Ha Long and Bai Tu Long Bays. These could be mature tower-free karst plains, or they could be lowlands with cores of clastic rocks in fault blocks; the multiple fault boundaries of the coal measure rocks on the adjacent mainland suggests that this is possible.

The juxtaposition of fengcong, fenglin and plain elements in the karst landscape is normal. Marginal karst plains are created where drainage from adjacent non-carbonate hills provides the most corrosive water; this increases dissolution of the limestone and also accelerates lateral planation around the active alluvial zone. The drowned plains across the inner parts of the bay are sited where drainage from the Red River and the mainland flowed onto the limestone. The patches of fengcong karst which now form the larger islands probably originated as areas of slightly higher ground or fewer dolines in the initial surface from which the modern karst evolved.

All the limestone surfaces on the Ha Long Bay islands are fretted by dissolution. The outcrops therefore evolve into complex and irregular shapes (Figure 10), distinguished by very sharp edges on the pinnacles, ridges and blades of remnant rock. These microlandforms on the metre scale all have surfaces of sharp karren ridges, runnels and pits on the centimetre scale. This creates an inhospitable terrain which is very difficult to cross. Jagged open fissures continue to depth and carry the rainwater into the cave systems beneath. There is no continuous soil cover. Largely organic soil accumulates in some limestone fissures, where it provides a rooting medium for the ubiquitous scrub vegetation; conspicuous larger plants include *Pandannus* and *Dracaena* (Dragon's skeleton). Rounded sub-soil karren forms have not been observed. Many walls and slopes in the more massive limestone beds are scored by rillenkarren that may be many metres long. All limestone surfaces are black due to their invasion by blue-green algae; these live in the surface crust of the limestone and aid its pitting by biogenic dissolution.

Marine erosion of the limestone

Marine invasion of the Ha Long Bay karst has added an extra element of lateral undercutting of the limestone islands. The most conspicuous feature is the main marine notch cut into all the rocky coastline (Figure 9). Its deepest zone is generally nearly 3 m high, occupying the levels between normal high and low tides. It is a complex feature, commonly with a shoulder at its mid-height and a lesser undercut extending another metre higher; the latter may represent erosion by high wave action and at spring high tides. Further notches at higher levels were cut at times of higher sea level and are no longer active. Features below low tide level have not been observed, but there is no evidence of any wide wave-cut platforms.

Across the bay, there is no variation in the size of the notches which relates to exposure to the larger waves that derive from the open sea. This indicates that the notches have been cut largely by dissolution of the limestone. Sea water is normally saturated with respect to calcium carbonate, and limestone dissolution is therefore dependant on aggressive micro-environments created by algae in the surface layers of the limestone. The dark crusts with blue-green algae, that are ubiquitous on the subaerial limestone outcrops, do extend down the cliffs into the tidal range; marine algal forms are probably equally widespread, but have not yet been documented. Limestone dissolution is also enhanced at sea level by the mixing of sea water and fresh water within the fissure systems of the islands. Notches are a feature of limestone coastal cliffs worldwide, but those of Ha Long Bay are exceptionally well developed, and at many sites extend back into arches and caves (see below).

Undercutting in the marine notches is presently the major process in the erosion and retreat of the limestone cliff faces. Marine erosion has not only added the notches to the profiles of the limestone islands, but it also maintains the steep faces of the fenglin karst towers, and thereby perpetuates the spectacular nature of the karst landscape.

Many of the bay islands have narrow peninsulas formed by high limestone ridges that are bounded by cliffs; these separate and overlook bays which are much wider than the intervening land fragments, as at the northern ends of Dau Be Island (Figure 5). Ridges that link chains of peaks are created in fencong karst where there are favourable patterns of large dolines. Under normal weathering conditions, these degrade into lower cols, eventually to leave isolated karst peaks. The very narrow limestone aretes of Ha Long Bay are not typical of subaerial fengcong karst. They are a consequence of more rapid lateral expansion of the intervening depressions, and appear to be a feature of marine erosion. Their presence indicates a significant component of marine action in the evolution of the Ha Long Bay geomorphology.

A few natural beaches have stabilised in the lea of some of the small islands; these are composed entirely of calcite shell sand. In the western part of the bay, north of Cat Ba Island, some islands contain small bays that are filled with sands and muds deposited in the outer zone of the Red River delta; mangrove swamps have developed on sediment surfaces which lie in the upper half of the intertidal zone, and small quartz sand beaches have formed between these and the limestone cliffs.

Figure 6. A small limestone tower on the east side of Bo Hon Island is a fine example of a fenglin karst tower, subsequently undercut by marine erosion, which carved the prominent notch and helped cause the recent rockfall from the right hand side.

Figure 7. View from above Titop beach on Cat Lan Con Island, past smaller island towers to the conical hills of Bo Hon Island.

Figure 8. Conical hills of the fengong karst forming Island #396 and Bo Hon Island, seen from the mouth of Bo Nau Cave.

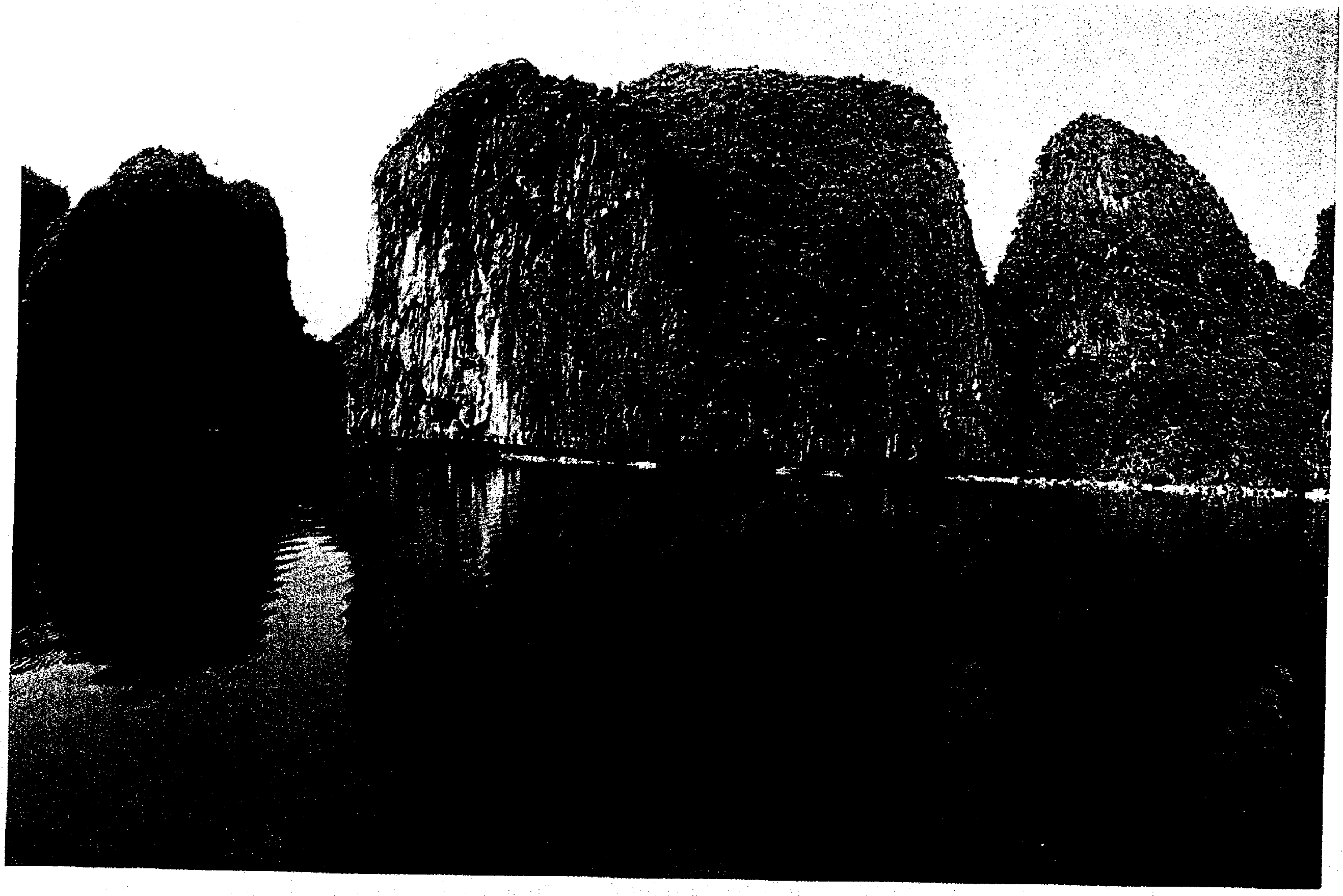


Figure 9. Limestone hills with cliffs undercut by a deep dissolution notch at sea level; these form the perimeter of the tidal lake in Bo Hon Island, which is reached only through the marine notch cave of Hang Luon, through the base of the hill on the left.

Figure 10. Nearly vertical cliffs on Ghenh Dang Island rise to a pinnacled crest; their limestone has long karren grooves etched into them by rainfall dissolution, and the island is breached by a fragment of old cave passage containing stalagmite false floors.

The limestone caves

The limestone islands of Ha Long Bay are entirely drained underground through infinitely complex systems of narrow fissures and through more open cave passages. There are no surface streams; all direct rainfall sinks rapidly into the open fissures. Enriched with biogenic carbon dioxide, this water continues to enlarge the fissures and so form new caves by dissolution of the limestone.

The lower part of the limestone is flooded by sea water which flows freely through the open fissure systems in the bases of all the islands. Secondary permeability of the karst limestone is so high that water tables in the islands are essentially horizontal, at sea level. The main groundwater movement is generated by tidal flow, which flushes salt water through the islands twice a day. This overshadows the small flows of rainfall input, and there is no evidence of lenses of fresh water existing in the limestone islands (the one reported fresh water lake must be perched on a geological structure as yet unknown). Caves are currently forming in the zone of active salt water flow, but dissolution rates and saturation indices have not yet been investigated.

Within Ha Long Bay, the main accessible caves are the older passages that survive from the times when the karst was evolving through its various stages of fengcong and fenglin. Three main types of caves can be recognised in the limestone islands:

1 remnants of old phreatic caves,
2 old karstic foot caves,
and 3 marine notch caves.

All three types are shown diagramatically in Figure 4; not shown in this figure are the networks of small fissure systems that are the main sites of present-day dissolution but are not yet large enough to be entered. The main caves recorded during preparation of this report are listed in their different groups in Table 1.

Remnants of old phreatic caves

Many of the bay islands contain fragments of large or small cave passages that are partly choked with debris, mud or stalagmite. These are clearly remnants of very old cave systems, that are no longer parts of the active karst drainage of the limestone. They were formed deep within the limestone long ago, when the ground surface was hundreds of metres above its present position. Most of these caves were phreatic, formed below the water table of the time. They were then the underground channels that carried drainage from the deep dolines and closed depressions, which allowed the karst landscape to mature through its various stages of fengcong. Subsequent lowering of the base level water table has left them dry and abandoned. Simultaneous lowering of the ground surface has cut into these old cave systems; parts have been totally removed by erosion, truncated fragments are now exposed in the tower walls and cone slopes, and other remnants remain preserved but hidden inside the limestone hills. They occur at all levels in the limestone islands, and are distinguished from the other cave types by their sloping passages and considerable vertical range. Active phreatic

1. Old phreatic caves	**2. Karstic foot caves**	**3. Marine notch caves**
Hang Sung Sot Dong Tam Cung Dong Lau Dai Dong Thien Cung Hang Dau Go Dong Huang Long Dong Thien Long	Hang Trinh Nu *in* Hon Xac Kho *in* Hon #152 *in* Hon Vung Ba Cua Hang Bo Nau Hang Tien Ong Hang Trong	Ho Ba Ham Hang Luon *in* Hon Vung Ha *in* Hon Bo Hung *in* Dao Cong Do
Tourist caves	**Archaeological caves**	**Bat caves**
Dong Thien Cung Hang Dau Go Hang Sung Sot Dong Tam Cung Hang Bo Nau	Dong Huang Long Hang Tien Ong *in* Hon Vung Ba Cua	Hang Sung Sot Hang Trinh Nu *in* Hon Vung Ba Cua Dong Huang Long Hang Bo Nau Hang Dau Go

Table 1. Known caves in Ha Long Bay, grouped in the upper row by their geomorphological origins, and in the lower row by their use and other values. Other caves are recorded, but were not inspected during this assessment; more caves are known only as entrances, but have not yet been explored.

caves must exist within the deeper limestone, but none has yet been found.

Hang Sung Sot is a large fragment of very old cave passage in Bo Hon Island (Figure 12). From the entrance chambers that are truncated at a balcony high in the cliffs, a passage more than 10 m high and wide descends gently to the south (Figure 13) and then rises to a massive choke of boulders and stalagmites; a small exit above this emerges in a chaos of fretted limestone under a canopy of vegetation. The main cave has various levels of flowstone and false floors, and ways may exist through the boulder floors into lower passages. There is some active stalagmite growth, and one dry basin is floored with cave pearls. In the large entrance chambers, the roof profile has been modified by collapse up to major bedding planes; these dip west at about 30°, but the main passage further into the cave is not controlled by the geological structure. Daylight reaches far into the cave, but the northern aspect prevents the intrusion of direct sunlight, and there are no phytokarren.

Dong Tam Cung is a large phreatic fissure cave developed in the bedding of the limestone which dips at 50°. Massive flowstone and stalactite development has divided the single fissure cave into three chambers, obliquely above each other, over a height range of about 20 m. There appears to have been only a single phase of cave enlargement, followed by draining as the base level and water table were lowered past it, followed by a single phase of calcite deposition (which continues today on a reduced scale). The cave is now accessible where its upper end is truncated by the receding cliff face of its host tower.

Dong Lau Dai is a cave with a complex of over 300 m of passages opening to the south side of Co Ngua Island (Figure 14). The main chamber has an entrance passage open to the cliff, while its southwestern end appears to be a choke of boulders, mud and stalagmite which is also truncated by the cliff. The passages to the north are on three levels, developed on separate bedding planes and each aligned along the strike where the dip is about 10° southwest; the levels may be sequential, but could be contemporary within an inclined phreatic maze. The cave has thick deposits of mud and large stalagmite formations, but stratified calcite floors have not been observed.

Dong Thien Cung and Hang Dau Go are two remnants of the same old cave system that both survive in the northern part of Dau Go Island at between 20 and 50 m above sea level (Figure 16). Thien Cung has one large chamber more than 100 m long, blocked at its ends and almost subdivided into smaller chambers by massive walls of stalactites and stalagmites. Flowstone and gour deposits cover part of its floor and also form remnants of false floors at higher levels; the whole cave is very beautiful. The roof is a spectacular series of phreatic domes. Both the accessible entrances are narrow fissures to the eastern slope of the island, and a large entrance also opens into the western slope. Low level passages (not marked on Figure 16) represent a later phase of development and are extensively choked with stratified mud. Hang Dau Go is a single large tunnel (Figure 15) descending along a major set of fractures to a massive choke. A high-level side chamber contains stratified sediments which have been excavated in the distant past; the style of the diggings suggests the extraction of nitrates. There are further cave entrances visible in the cliffs of the island, including that of Dong Thien Long, which indicate that there may be further remnants of an extensive cave system preserved within the limestone.

Dong Huang Long is a short cave entered at beach level on Cap Lom Island. A chamber over 12 m high has remnants of calcite false floors high on its walls, and a soaring shaft breaks through its roof. Two passages end in chokes; a small passage at the top of the steep ramp of terraced stalagmite and gours in the main chamber extends to the lip of a shaft. A small stream of clean water emerging half way up the calcite ramp and flowing over the clean flowstone has the largest flow (about 1 litre per second) of any invading vadose drainage yet observed in the Ha Long Bay caves; this is indicative of the ongoing process of vadose cave development.

Truncated fragments of many other very old caves are exposed in the island cliffs. They occur at various altitudes up to 50 m above sea level. Some are partly filled with calcite and clastic sediments, and flowstone false floors are common; others remain as open tunnels.

The sea cliff on the south side of Cong Thau Trong Island exposes a vertical section through a breccia pipe. This consists of a column of limestone blocks which have fallen progressively from the roof of a cave, so that the void has migrated upwards. The original cave lies below sea level; a small void remains on top of the pipe beneath an arched roof.

Old karstic foot caves

Foot caves are a ubiquitous feature of karst landscapes which have reached a stage of 'widespread lateral undercutting at base level. They may be quite small notches at the foot of limestone cliffs, or they may extend back into maze caves or into stream caves draining from larger cave systems within the limestone. They are distinguished by the main elements of their passages being close to horizontal, and they are commonly related to rock or sediment terraces that were a function of base level erosion or deposition. Remnants of foot caves may be confused with elements of old phreatic caves which are horizontal solely because they have been formed along the bedding in horizontal limestones or along the strike in dipping limestones; many essentially horizontal foot caves may be seen to cut across geological structure. There are no active foot caves in Ha Long Bay, because the sites of their development have now been invaded by the sea to become the marine caves.

Hang Trinh Nu is one of the larger foot caves in Ha Long Bay (Figure 17). It extends beneath a conical hill and right through a peninsula on Bo Hon Island, between the entrance and the bay overlook exit that are about 80 m apart. The main passages are all at the one level, with their ceilings at about 12 m above sea level. Floor heights vary, due to accumulation of stalagmite in the narrowest section, and due to apparent undermining by a lower level in the southern daylight chamber. Two large shafts rise into darkness from the roof of the same chamber. Notches are cut into the walls at various levels and are partly filled by stratified calcite and clay; they are evidence of multiple stages in the cave's development.

An unnamed foot cave extends for 40 m right through the small island of Xac Kho (Figure 18). The main tunnel is at its widest about 6 m above sea level; at the same level it extends into smaller side chambers and a passage which rises gently along a bedding plane. Both the latter and a section with a tubular profile 8 m in diameter may represent relics of

an earlier phreatic cave.

A foot cave on Island #152 has a single, horizontal passage with an elliptical profile 5 m high and over 15 m wide. It extends 100 m to a choke of flowstone and gour dams, and may continue further. Phreatic roof domes rising up to 4 m show that it was not entirely cut by lateral planation; these are relics of phreatic enlargement, as are typical of foot caves. Hang Bo Nau is a horizontal cave about 70 m long, containing old stalagmite deposits; it is notable for the way that its passage clearly cuts across the 25° dip of the limestone bedding.

Vung Ba Cua Island has a remnant of large old phreatic cave that completely breaches the narrow limestone ridge linking to its northeastern peninsula. Almost below it, a foot cave extends in 50 m at just above sea level; its roof is a calcite false floor, and there appears to be another foot cave passage at a level about 8 m higher. Thick clay in the lower passage has been worked for pottery; the cave does lie in Ha Long Bay's western zone of invaded more by clastic sediment from the Red River delta.

Remnants of marine oyster beds survive cemented to the walls of some of the old foot caves, including Hang Trinh Nu, Hang Tien Ong and Dong Huang Long. They date from times when the caves were temporarily invaded by high sea levels. A concentration of the oyster beds at around 6 m above sea level may correlate with terraces at that altitude around the Red River delta, which are ascribed to mid-Holocene times.

Marine notch caves

The ultimate zone of lateral undercutting is sea level, where rock structures are powerfully eroded and eventually reduced to a wave-cut platform - the ultimate planation surface. All rocks are eroded by wave action to create cliff notches, and small sea caves are selectively formed on structural weaknesses. Limestone is even more susceptible to sea level erosion, due to its dissolution by the sea water. Since their invasion by the sea, the karstic hills and towers of Ha Long Bay have been modified by marine erosion; the process continues today. Dissolution of the limestone allows the cliff notches readily to be deepened and extended into caves; many of these sea-level extend right through the limestone hills, into drowned dolines which are now tidal lakes or adjacent bays. A distinguishing feature of these marine notch caves is an absolutely smooth and horizontal ceiling cut through the limestone. Many of these caves also have phreatic roof domes recessed into their otherwise flat ceilings, and it is likely that part of their development was as subaerial foot caves, with components inherited from even older phreatic caves.

One of the most unusual and distinctive features of Ha Long Bay is the Ho Ba Ham group of hidden lakes and their connecting caves in Dau Be Island (Figure 5). From the island's perimeter cliff a cave extends about 150 m to Lake #1; it is 10 m wide at water level, and curves so that the centre is almost dark and requires some care when passing through in a boat. At low tide there is a minimum of 1.5 m of airspace, over water that is at least 2 m deep. The second cave, through to Lake #2, is of similar cross section but only about 60 m long. A cave through to Lake #3 is smaller, and may only be traversed by a canoe; it is not known what links there are to Lakes #4 and #5. In the two larger caves, most

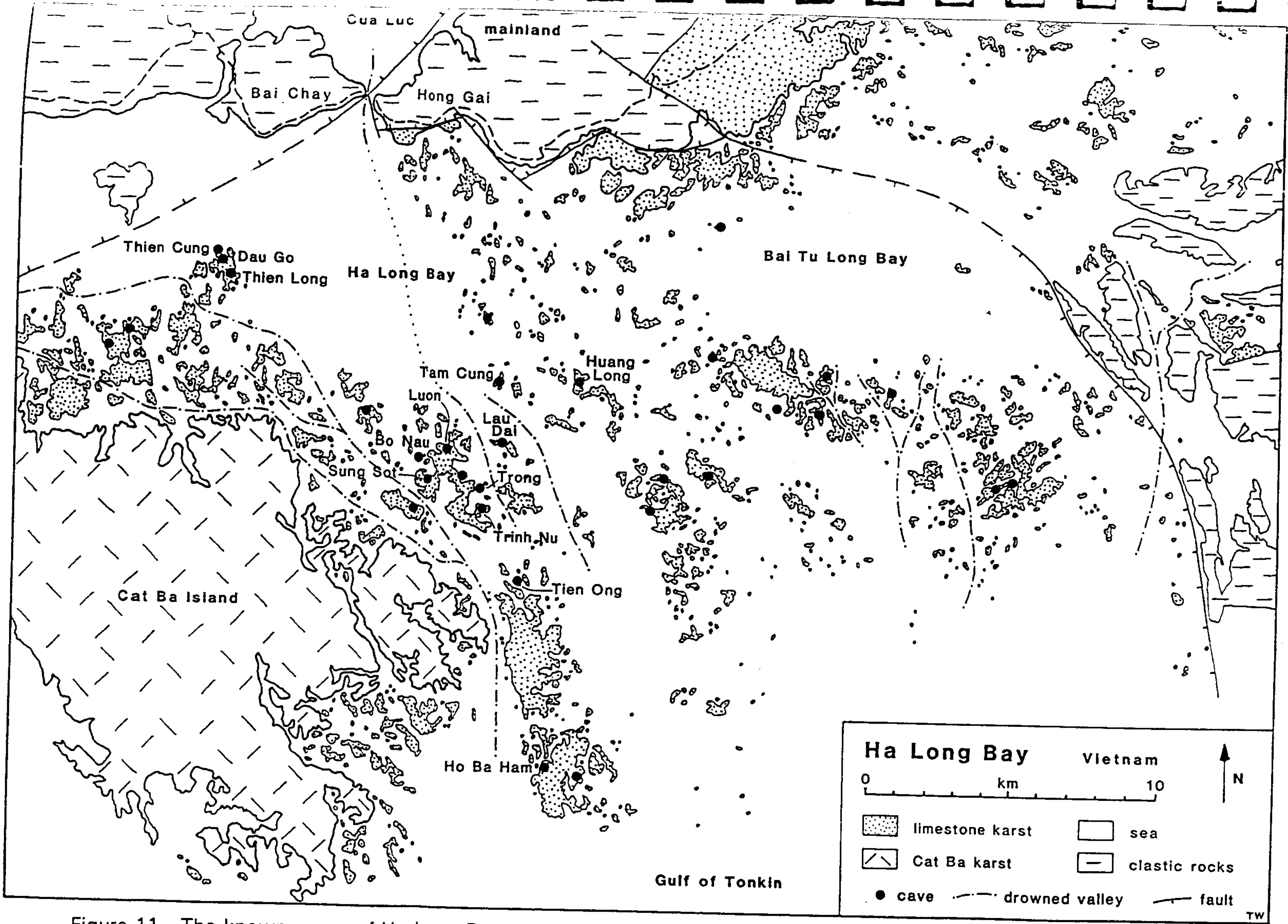


Figure 11. The known caves of Ha Long Bay, the drowned valleys (from available map data), and the boundary faults.

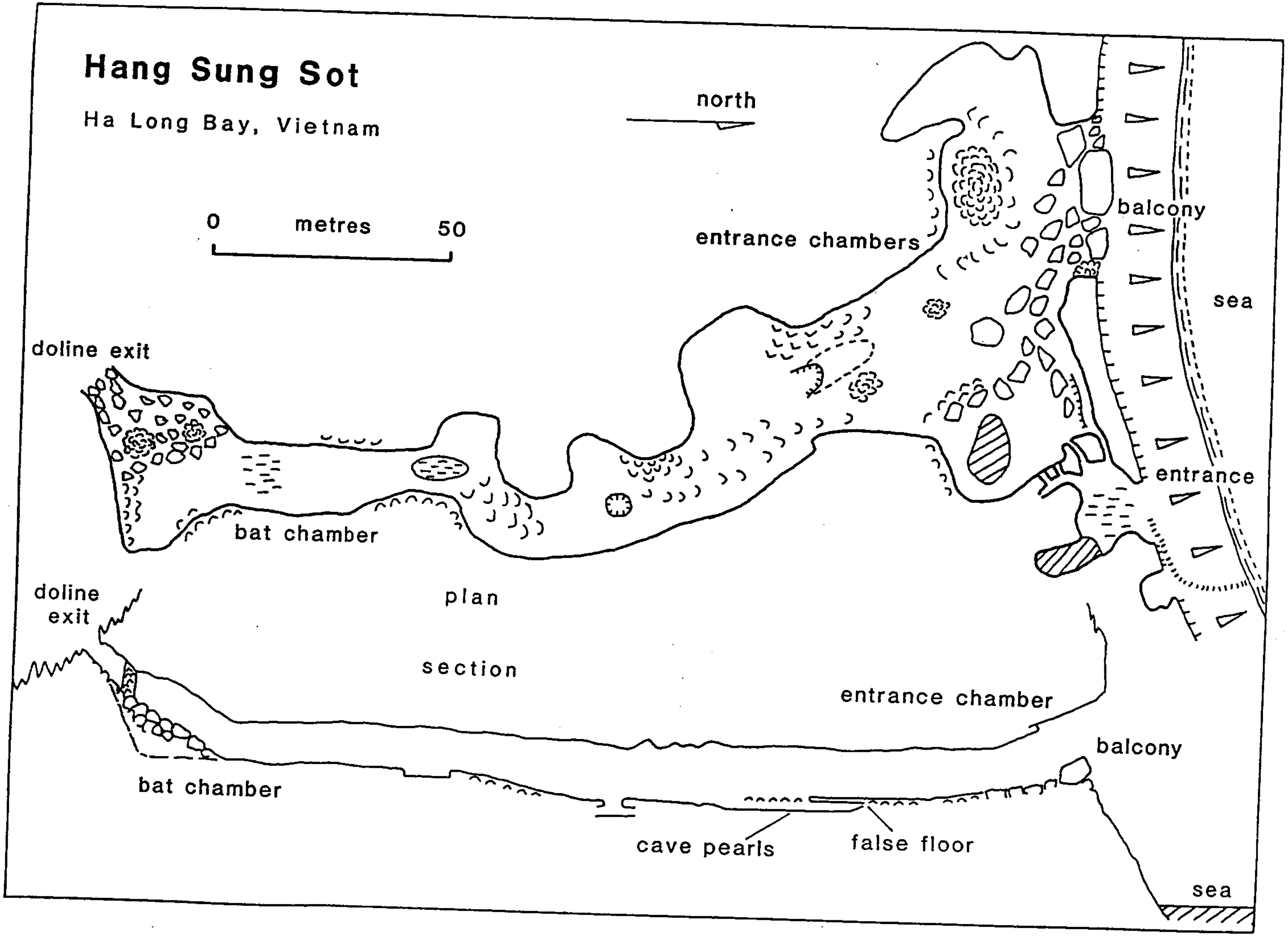


Figure 12. Sketch survey of the old phreatic cave of Hang Sung Sot, on Bo Hon Island; key to the symbols is in Figure 20.

Figure 13. Looking into the entrance chambers of Hang Sung Sot from the fallen roof blocks in the cliff face balcony opening.

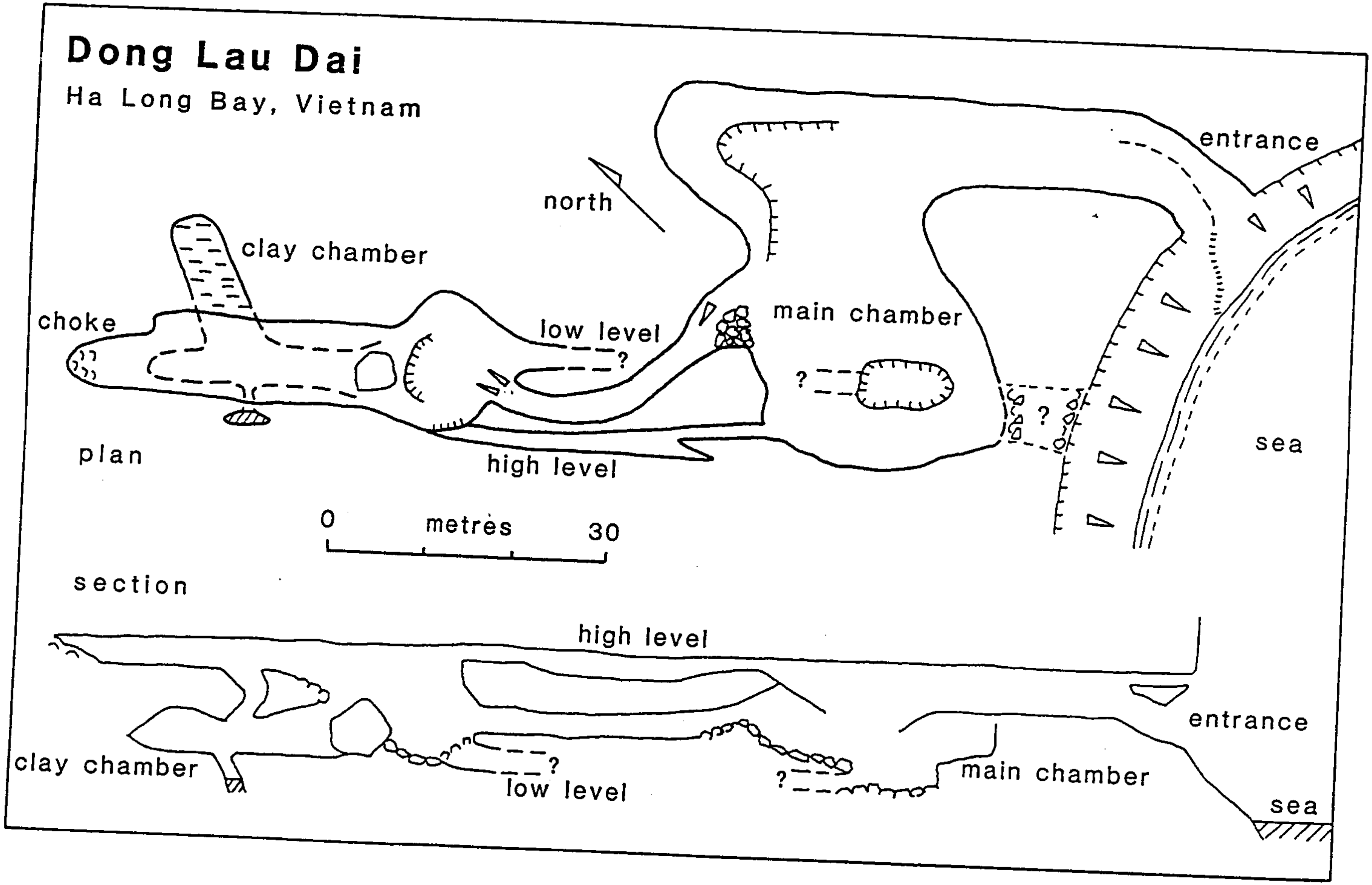


Figure 14. Sketch survey of the old phreatic cave of Dong Lau Dai, on Co Ngua Island; key to the symbols is in Figure 20.

Figure 15. Looking along the single large passage in Hang Dau Go; plants cover the old calcite formations in the daylight zone.

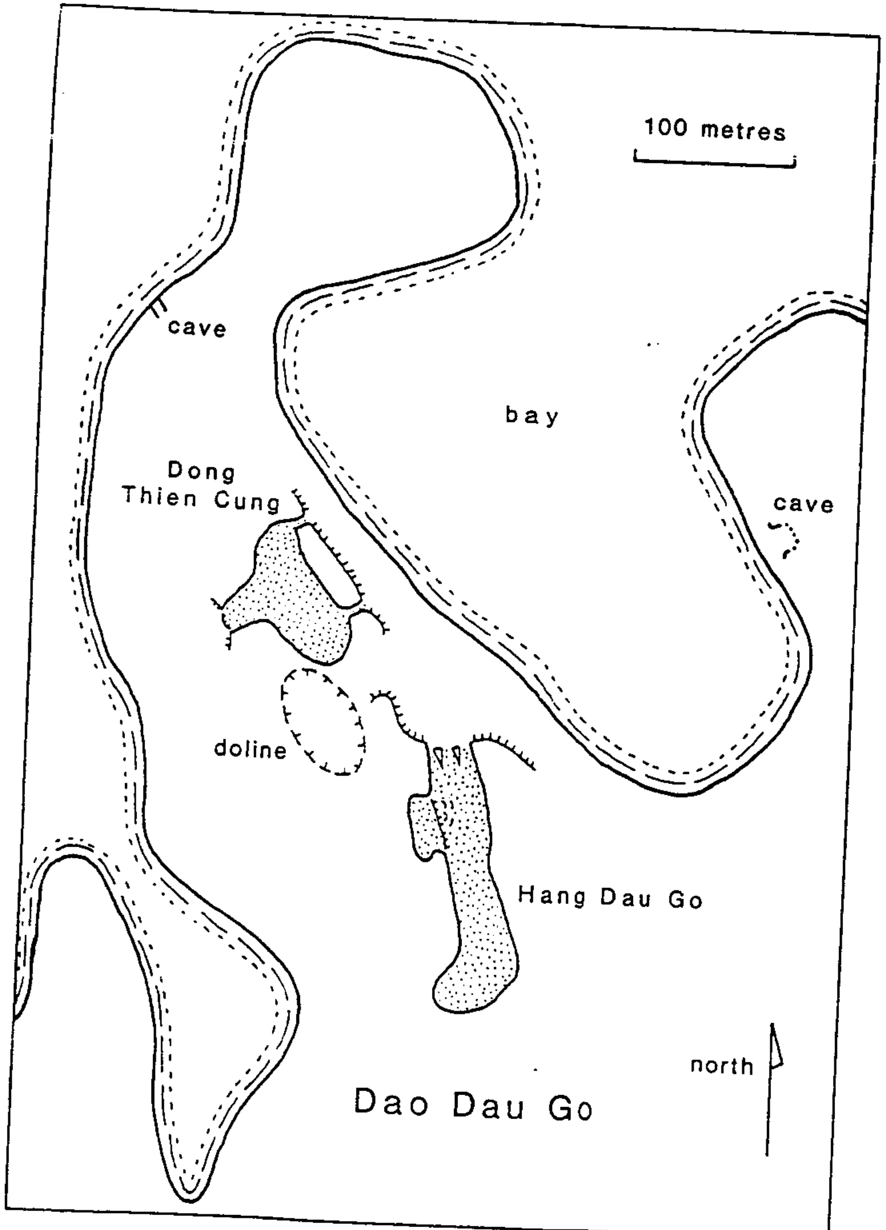


Figure 16. Outline map of the known cave remnants at the northern end of Dau Go Island.

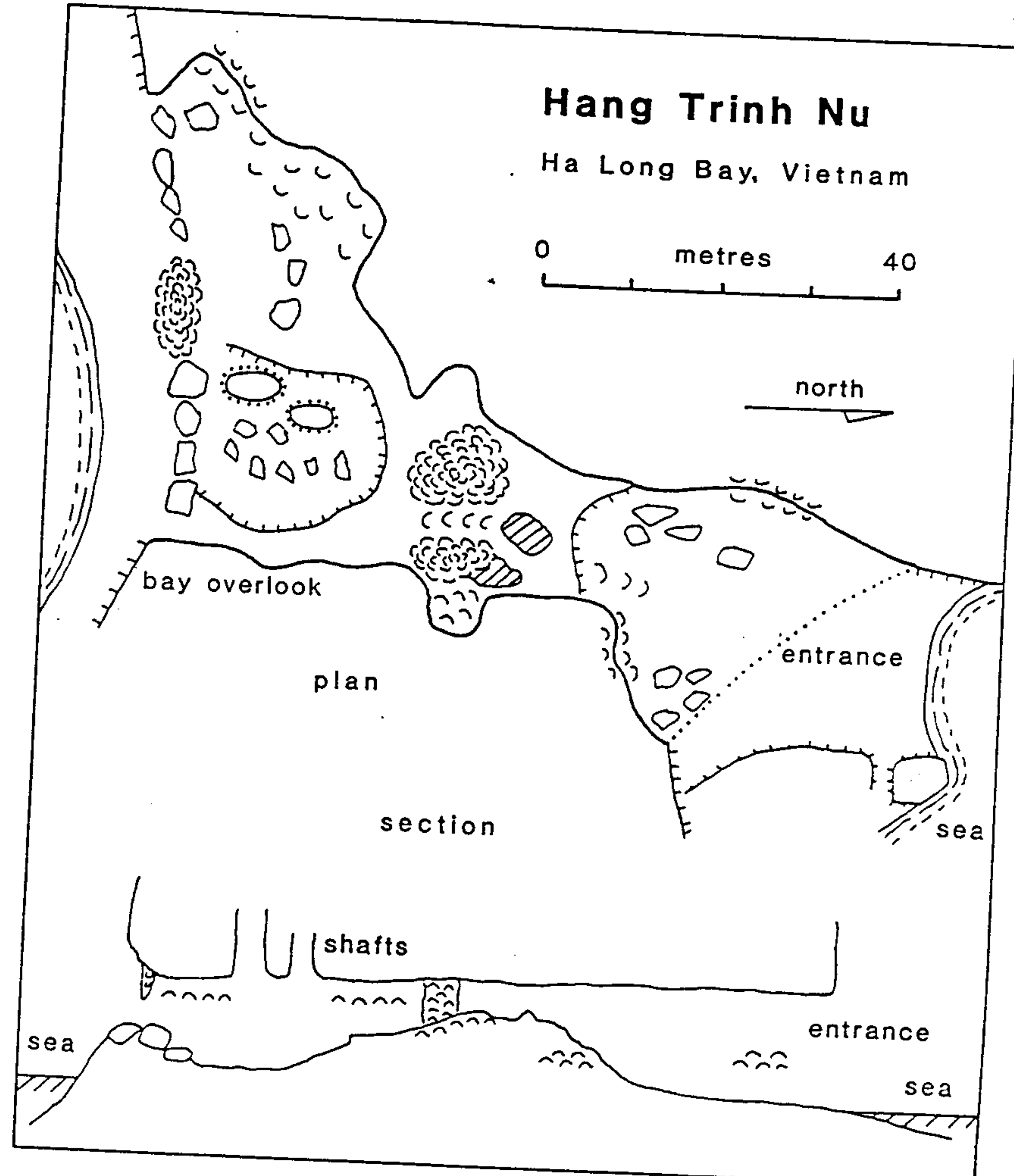


Figure 17. Sketch survey of the karstic foot cave of Hang Trinh Nu, on Bo Hon Island; key to the symbols is in Figure 20.

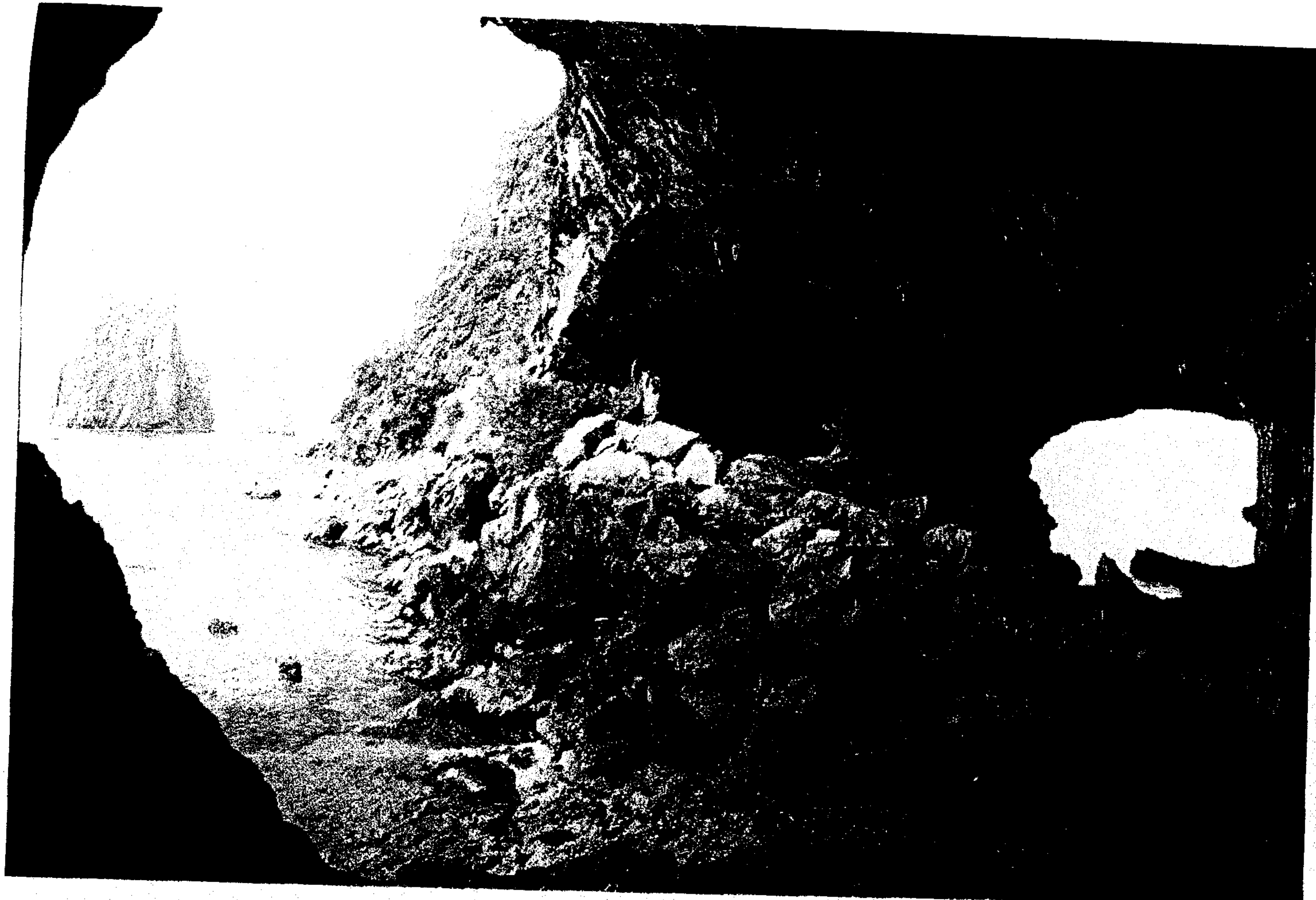


Figure 18. The old karstic foot cave which passes through a narrow limestone ridge in Xac Kho Island, just above sea level.

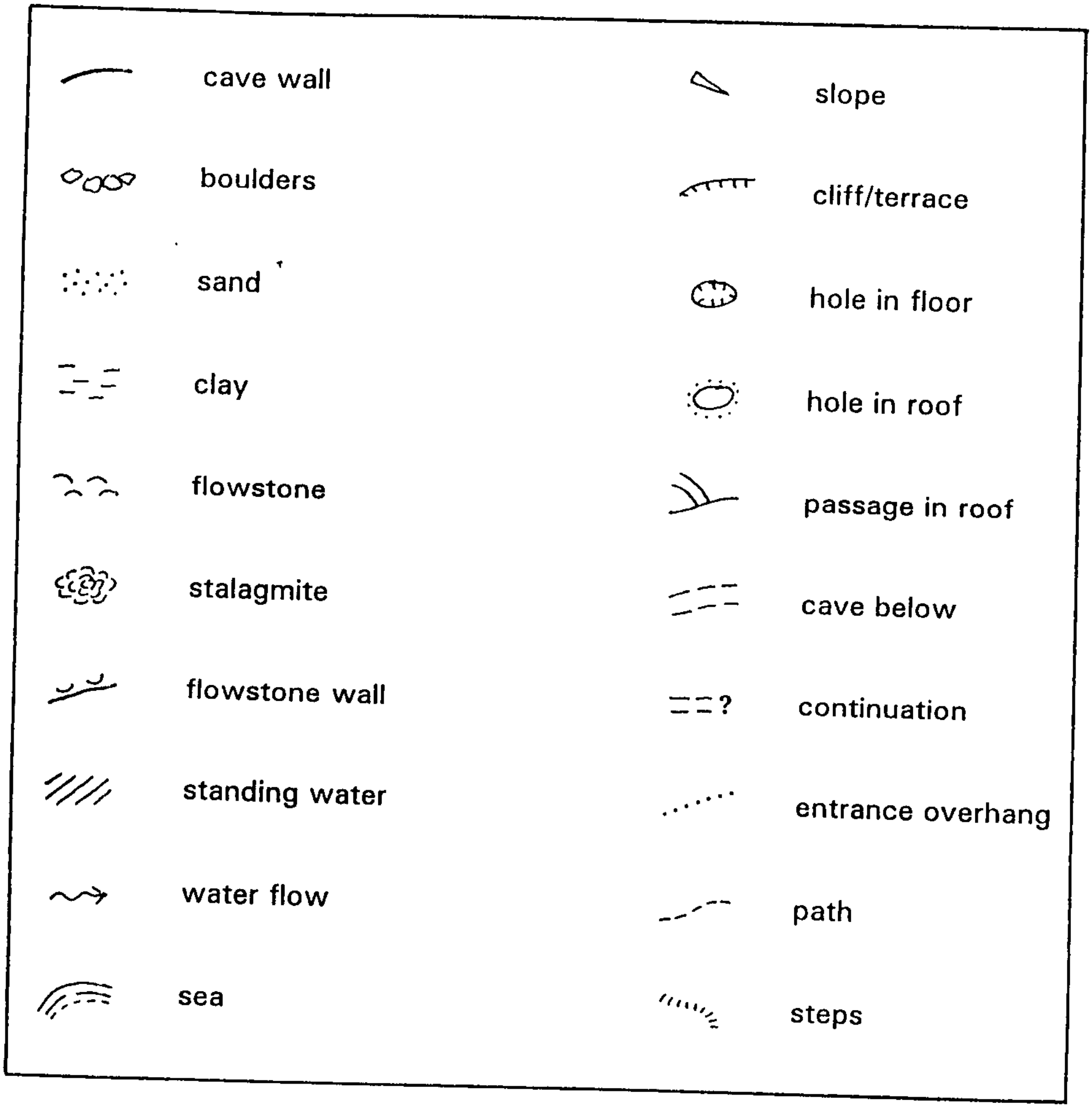


Figure 20. Key to symbols used on the cave surveys.

of the ceiling profile is a perfectly flat surface cut into the limestone; these smooth surfaces can only represent corrosion levels. Bulbous stalactites up to 1 m in diameter hang from the cave roofs; they have not been eroded or planed in the style of the rock ceilings; though some are active with dripwater, their size suggests the antiquity of both them and their host caves.

There are similar marine caves at many other sites in Ha Long Bay. Hang Luon extends 50 m through to an enclosed tidal lake (Figure 9). An unnamed cave extends about the same length into Lake #6 on the east side of Dau Be Island (Figure 5), and notch caves link adjacent bays on the west side of Vung Ha Island and on the south side of Bo Hung Island. A cave into the eastern tip of Cong Do Island carries sea water in and out of a drowned doline lake; its passage is about 4 m high and wide, and it is a very fine stream cave in clean rock, unusual only that its flow reverses with the ebb and flow of the tide. These caves range in width from 8 m to 20 m. They have phreatic domes in their ceilings, and parts of them are breaking upwards in fractured limestone to create low stable arch profiles. They all have some sections of roof that are bevelled flat, but these corrosion levels are all a few metres above present high tide levels. Hang Luon has a massive stalactite hanging 2 m down from a flat roof, and the stalactite is truncated at the modern high tide level. Most of these marine cave tunnels pass directly beneath limestone hills, and show no relationship to the peaks and cols of the surface profile above them.

The flat ceilings in the marine caves are above present high water levels, and many of them are draped with stalactites. They are clearly old erosion surfaces, created largely by dissolution in times past when sea levels were higher in the Pleistocene. Many of the caves have phreatic roof domes that are relics of their early origins as foot caves, and it appears that their modification by marine erosion is also largely a feature of erosion in the past, though further erosional modification does continue today.

Evolution of the landscape

While the processes of landscape evolution in Ha Long Bay may be broadly appreciated from a short visit, there are as yet no absolute dates measured for any of the area's sediments or geomorphic features. Comments on the time scale of the processes must therefore be regarded as tentative.

Karstic evolution of the limestone must have continued through much of Neogene time (20M to 2M years ago), as mature fengcong and fenglin landforms can only evolve through millions of years of erosion and surface lowering. In panoramic views across the bay islands (Figure 7) there is generally little suggestion of any concordance of summit heights that could relate to intermediate Neogene erosion levels. Remnants of old phreatic caves survive at various levels within the bay islands, but their altitudes are not easily related to their ages.

The Cong Thau Trong breccia pipe is a feature of a collapsing cave at a lower level. Active phreatic caves must exist in the limestone that is as yet unseen below sea level; the development and enlargement of new caves is a continuing process beneath an evolving karst landscape.

The topography of the bay's sea floor is only known from the limited available map data, but it appears that most of it has very little relief, and the great proportion lies at depths of less than 10 m. This morphology is compatable with an origin as a subaerial karst plain, which has been subsequently drowned by the sea. The extent of karstic foot caves into the limestone hills at the edge of this plain (and therefore now below sea level) is unknown.

The major impact on Ha Long Bay of the worldwide climatic oscillations during the Pleistocene (Anthropogene) was the periodic lowering of sea level. During cooler stages, water was locked into the icecaps of higher latitudes, and sea level temporarily declined by about 100 metres. This happened at least four times, and between these events sea levels were close to those of the present day. When the sea level was low, the whole of Ha Long Bay was dry land. Subaerial karst processes continued on the limestone basins and plains between the cone clusters and towers. Allogenic drainage from the north fed rivers across the bay area. These excavated valleys are now drowned (Figure 11), but none reached contemporary sea level until they were far to the south of the modern bay site. Limited available mapping of the bay's sea floor indicates that, though these drowned valleys reach depths of 20-30 m below present sea level, they are discontinuous and do not continue to deepen to the south (downstream). They may represent segments of valleys that lay between caves carrying their rivers through intervening limestone ridges. Alternatively, the sea floor bedrock topography may be masked by extensive accumulations of clastic sediment. The main open part of Ha Long Bay has a floor of thick sediment; large ships to and from Cua Luc have to follow a channel that was excavated through this, but is now kept clear by natural scour.

Low sea levels existed only during the cold stages of the Pleistocene, and these probably account for a total of less than 200 000 years (out of nearly two million years of Pleistocene time). Karstic evolution in these short interludes would have been rejuvenated, so that dolines would have been deepened, while the cones and towers would have been degraded; the overall effects on the landscape would have been small - except for valley modifications which are now unseen below sea level.

Many of the caves now at or just above sea level were occupied as shelters during the Soi Nhu cultural period, between 18 000 and 12 000 years ago, when sea levels were low during the Devensian glacial stage. The cave dwellers left behind vast banks of freshwater and terrestrial gasteropod shells (dominated by *Melania* sp) which testify to the remoteness of the contemporary sea; some of these shell banks have subsequently been cemented to the cave walls by calcite deposition.

Marine undercutting of the limestone islands at sea level is a conspicuous feature of Ha Long Bay. Its extent is more than could have been created solely in the Holocene; the many limestone ridges that have been reduced to narrow aretes by coastal retreat are indicative of a long period of marine erosion. Much of the marine morphology of the limestone islands dates from the warmer phases of the Pleistocene when sea levels were close to that of today. The complex marine cliff notches and the multiple levels of dissolution features in the associated notch caves further indicate that sea level erosion has been active over a long period of time, when sea levels have not been absolutely constant.

The marine invasion of the Ha Long Bay karst is ultimately attributable to tectonic subsidence of the region. The exposure and subsequent drowning through each climatic cycle of the Pleistocene were mere interludes in the geomorphic evolution of the site. The critical tectonic subsidence may have been in the late Neogene or in the early Pleistocene; there is as yet no firm evidence to ascribe a reliable date to the event.

Geology of Ha Long Bay

The islands of Ha Long Bay are all cut in a folded sequence of Carboniferous and Permian limestones that reaches to more than 1000 m thick. These pale grey limestones are strong, fine-grained materials ideal for the development of karstic landforms. Beds vary from 500 mm to 5 m thick, and fracture spacing is normally between 1 and 10 m. Very thin shale partings occur on many of the bedding planes, but thick shale beds have not been observed. Chert horizons and nodules are minor features, and patchy dolomitisation has been observed at only a few localities.

Across most of the bay, the limestones dip to the west, but the structure appears to be compilcated by north-south faults which have not yet been mapped in detail. Cat Ba Island is distinguished by limestone hills with lower slope angles than are typical of the bay islands. It appears to be formed largely in a more thinly bedded series of Carboniferous limestones underlying those of the bay; the boundary of the underlying bedded limestone and the overlying massive limestone is exposed dipping at about 20° north across the southern part of Vung Ba Cua Island. At the eastern boundary of the limestone islands, the limestone dips away from the Devonian sandstones which form Ngoc Vung Island; there is no intervening outcrop of underlying thinly bedded limestones, and the boundary is probably along a major cross fault which is recognisable on the mainland (Figure 11). The limestone may be thickened by overthrusting, which has been observed in one island cliff. The small areas of karst landscape on Van Canh and other of the eastern islands are formed on Devonian limestones that occur within the mainly clastic sequence.

The mainland north of Ha Long Bay is formed largely of Triassic coal measures. These are complexly folded and contain anthracite seams up to 50 m thick, which are mined in large open pits. The coal measures are confined between major east-west faults and are also broken into blocks by subsidiary cross-cutting faults. Their boundary with the limestone is almost along the coast, and structural relationships suggest that this is also faulted. It appears that the block patterns within the coal measures probably continue into the limestones of Ha Long Bay, but these have not yet been recognised by detailed mapping. The geological structure of the Ha Long Bay limestones appears to be very complex, and some of the drowned valleys between islands are probably fault-guided. Bedding is close to horizontal in the eastern part of the bay (around Cong Do and Van Gio Islands), but elsewhere dips at any angle, and small overfolds occur in the western part of the bay. The structure has little influence on the karst geomorphology, as slope profiles on the islands are largely independant of the limestone dips.

Significance and value of the site

The remit of this report was to summarise and assess the geomophological aspects of the Ha Long Bay World Heritage Site.

Importance of the karst geomorphology

The geomorhology of Ha Long Bay may be described as unique. Fenglin tower karst, of the type present in much of Ha Long Bay, is the most extreme form of limestone landscape development. The world's type site, and its finest example, is in the Yangshuo region of the Li River basin, in Guangxi, southern China. If these karst landscapes may be broadly compared in terms of the height, steepness and number of their limestone towers, Ha Long Bay is probably second to Yangshuo in the entire world.

In addition, Ha Long Bay has been invaded by the sea, so that the geomorphology of its limestone islands are at least in part the consequence of marine erosion. The marine invasion distinguishes Ha Long Bay from the Yangshuo area, and adds another component to its geomorphological significance. There are other areas of tower karst invaded by the sea, notably on the west coast of Thailand, but none is as extensive as Ha Long Bay.

There is no doubt that Ha Long Bay is of international significance as a limestone karst landscape which is fundamentally important to the science of geomorhology. It contains the full range of fengcong and fenglin landforms, and also has a large suite of active caves and ancient cave remnants, whose clastic and calcite deposits record a long history of landscape evolution, not yet elucidated in detail.

Ancillary values of the site

Other values of Ha Long Bay are outside the specific remit of this report, but their existence should be noted, as they are elements which are characteristic of a limestone karst and do contribute to the overall site value.

Biodiversity is normally significant in karst regions where the individual limestone hills and caves create isolated ecosystems protected from external evolutionary pressures. This must apply to Ha Long Bay, where the small islands present totally isolated environments. Sung Sot Cave has already been recognised as a significant snail site. Bats have been observed roosting in a number of caves (Table 1), but neither cave swiftlets nor their nests have yet been recorded.

Many of the bay's caves that have large open entrances have been utilised or occupied in the past; known archaeological resources (Table 1) date from the late Pleistocene Soi Nhu culture, from the mid-Holocene Ha Long culture and from historical times. Vung Ba Cua Island has two unnamed caves of note; one in the northeastern isthmus contains pottery relics and also diggings which appear to have been the source of the clay material for their manufacture; a cave at sea level on the west coast of the island has figures painted with red ochre on its roof; both sites probably post-date the Ha Long culture. Dau Go Cave has

diggings which appear to have been to extract nitrates from the cave sediments.

The scenic values of Ha Long Bay are beyond question and are demonstrated by the scale of the local tourism industry. The large numbers of rocky islands rising almost vertically from the calm waters of the bay do create singularly beautiful panoramas.

Threats to the environment

Ha Long Bay is like any other accessible and populated region in that there are multiple pressures on land use and resource exploitation. Conflicts are inevitable and the aims of good nature conservation have to be placed in their proper local context.

Large scale threats

Ha Long City and Cua Ong are significant ports of long standing. The new port of Cai Lan, in the Cua Luc estuary, is already under construction; this is designed for an annual capacity of over 3 m tonnes of freight, to make it a major feature in Vietnam's infrastructure on the scale of the existing port at Haiphong. Large ships already cross the bay to reach the ports; the main channels thread between the limestone islands across the centre of the World Heritage Site. The visual impact of the large ships is acceptable, even if only because it is unusual. Inadvertant pollution from fuel oils has negligible impact on geomorphological values of the site (though ballast water should be dumped far outside the bay). Any removal of islands to improve the shipping lanes would be inappropriate and should be resisted.

Coal mining is a major industry on the mainland immediately inshore of Ha Long Bay, where large opencast pits yield over 3 m tonnes of coal per year. The pits are vast operations creating ten times as much rock debris as coal. Tip heaps are proportionately large but are well controlled; they are advancing over hill country and farm land, but have no impact on the bay. From the pits and coal washing plants, rock waste and coal fragments enter the bay at unknown rates; however, these are probably no greater than rates of natural sediment transport that would occur from the hills were they not mined. Most of the coal is transported through Ha Long Bay in barges destined for Haiphong or transfer to ocean-going ships. Coal barges were observed to be generally sheeted; pollution from them appears to be minimal, but quantities of coal may enter the bay at ship loading points. The mines are barely visible from the bay. The coal mining operations have negligible impact on the geomorphological values of the Ha Long Bay karst.

There is no perceived threat from quarrying of the limestone within the bay; resources are available elsewhere, and there is no need to exploit the limestone in the bay.

Hotel and tourist infrastructure development on a large scale within the bay would not be appropriate; this is not foreseen. Additional hotel developmemt in Bai Chay should present no threat to the bay, and the traffic in tourist boats could increase with no detriment to the environment if properly controlled.

Rubbish and sewage are inevitable byproducts of the urban areas of Ha Long City, with their total population approaching 200 000. Much of the waste now reaches the bay, and

remedies to this depend on improvements to the urban infrastructure. These are in progress, and are in a state of continuing evolution. Every improvement will benefit the bay, but the pressure and action for such can only derive through the city management; the presence of the World Heritage Site can only act as an added incentive.

Small scale threats

Ha Long Bay is the centre of a valuable fishing indutry, which is reliant almost entirely on small boats. Though this may have considerable impact on the marine fauna of the bay, it has no impact on the limestone geomorphology. Fish farms, oyster farms and clusters of fishing boats sheltered among the islands cause no geological harm; scenic values are generally enhanced by the interaction of natural and human aspects. A large fish farm that was in Ho Ba Ham Lake #2, in 1995, has been removed and has left no trace. Extraction of coral for sale in tourist markets has been greatly reduced, and should be totally stopped.

Mangrove swamps are a feature only in the peripheral buffer zones of the World Heritage Site. They are reported to have suffered depletion through over-extraction. They are beyond the scope of this report, but may warrant appropriate investigation.

Many of the caves in the limestone islands have attracted "improvements" and development to make them more accessible for visitors. Some sites have been damaged by excavation and path construction. Tourist visits are now restricted to just five caves (Table 1). Thien Cung has been equipped with good paths and lights, and is designed to be the main cave attraction. The unnatural coloured lights mimic the inappropriate fittings in Chinese tourist caves, in the belief that this is what visitors want to see. Natural white lights are more appropriate in a World Heritage Site; visitors will ultimately appreciate the natural environment of the caves if it is presented to them constructively. The other four caves are being kept in a more natural state with white lights and minimal pathway fittings. With the exception of the coloured light installation, the caves within the World Heritage Site now appear to be well managed, in a manner that creates minimal impact on geomorphological site values and yet allows appropriate visitor access and tourism utilisation.

The bay's traffic in tourist boats is increasing rapidly; it is a long way from causing significant impact on the site's geomorphology, but its expansion warrants monitoring and appropriate control where necessary.

An ongoing problem in Ha Long Bay is the accumulation of litter. This is generated by all users of the bay. Fishermen, bargees, tourist boat staff and local visitors alike dump rubbish wherever convenient, including over the boatside into the bay. Sea-borne flotsam is derived partly from land sites and partly from boats; it is all then washed into backwaters and onto the few beaches, where it is an unsightly and growing problem. It is not harming the geomorphological site values, but it is inappropriate to a World Heritage Site. Despite the prohibition of littering by the Vietnamese Law on Environment Protection, litter prevention and rubbish removal are not always part of the way-of-life in Vietnam; Lau Dai Cave was first entered only two years ago, but a tragic amount of empty bottles and food wrappings already spoil what was a pristine site. Unsightly litter will only be eliminated when public

awareness campaigns have modified local practise; such campaigns are the responsibility of national and local government, but the bay's management team should encourage their progress. It would be a good start to totally ban the overboard disposal of rubbish, which is the current practice of the tourist boats, and is within reach of management influence.

Future actions

The immediate future of the Ha Long Bay World Heritage Site can be viewed within the two fields of conservation and appreciation.

There are no apparent threats to the geomorphological values of Ha Long Bay; these are the most fundamental to the site, because they represent the justification for its conservation. The mainland coal mining industry and the port development should be able to co-exist alongside the World Heritage Site. The mining directly employs thousands of people, and will be a major element in the local economy for many years to come; the new port facilities are a significant factor in Vietnam's infrastructure expansion. Under sensitive and appropriate management, neither presents any threat to the geomorphology of the World Heritagge Site. Biological values of the site could perhaps be damaged by the pollution that is almost inevitable with major new industrial development; that aspect is beyond the remit of this report. The primary value of Ha Long Bay is in its magnificent limestone karst landforms, and these would not appear to be threatened by proposed and likely developments for the adjacent mainland areas. Planning control should ensure that future site use does not become inappropriate, and should continue to maintain and clean up the facilities and environment of the bay.

There is a notable shortage of scientific data recorded for Ha Long Bay. Such a significant scientific site warrants proper documentation. Only then can its values be fully appreciated. The database for the important karst geomorphology currently consists of little more than topographic maps. It is recommended that a programme of scientific study of the bay is instigated and funded. In the first stage a competent team of cave scientists and surveyors should produce an atlas of maps and documentation of the many caves within the bay. The cave maps should then be a basis for a geomorphological study with dating of sampled materials to allow construction of a chronology for the erosional evolution of the site. With this data to hand, Ha Long Bay will be more fully understood and appreciated, and will thereby be worthy of its World Heritage status.

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